STUDY: LEAD HAZARDS IN HOUSING

Childhood Lead Exposure in Washington's Communities

COMMUNITY, TRADE, AND ECONOMIC DEVELOPMENT

DECEMBER 2005

ACKNOWLEDGMENTS

The 2005 Legislature commissioned this study in SHB 6090, Section 127.

A state, general fund appropriation of $20,000 was allocated to the Washington Department of Community, Trade and Economic Development (CTED) "to compile a report on housing stock in Washington state to identify areas of potentially high risk for child lead exposure."

The Legislature directed CTED to include in this report:

1) An analysis of existing data regarding the ages of housing stock in specific regions; and

2) An analysis of data regarding actual lead poisoning cases, which shall be provided by the Department of Health's Childhood Lead Poisoning Surveillance program.

This study was completed by Cascadia Consulting Group under contract to the Washington State Department of Community, Trade, and Economic Development (CTED). Faculty and staff at Duke University, the University of Washington, and the Washington State Department of Health contributed greatly to this study through statistical analysis, including development of the estimation model used, as well as providing data, guidance, and review. The Washington State Department of Ecology also contributed data to the study. Layout, design, and printing of this report were completed by the Washington State Department of Printing.

This study was funded by an appropriation from the 2005 Washington State Legislature and grants from the U.S. Environmental Protection Agency and the U.S. Department of Housing and Urban Development.

More information about this study and additional copies of this report may be obtained through CTED's lead website: www.cted.wa.gov/lead.

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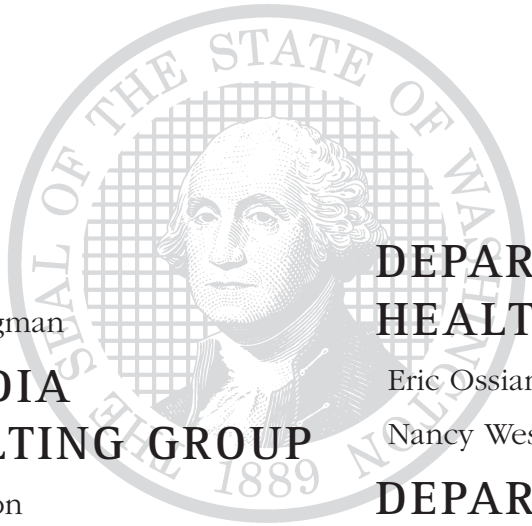

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EXECUTIVE SUMMARY

Lead-based paint is the most common source of childhood lead poisoning in the United States. Lead exposure in the home – from paint chips, dust, and other sources – can lead to adverse health effects ranging from anemia and behavior problems to irreversible brain damage or death. Younger children are particularly vulnerable and can experience lifelong health problems and learning disabilities. Lead was banned as an additive in residential paint in 1978, and the problem of lead-based paint is more common in homes built before the mid-20th century. These homes generally contain paint with a higher lead content and have had more time to deteriorate.

To learn more about this problem in Washington State, the Legislature directed the Department of Community, Trade, and Economic Development (CTED) to conduct a study identifying the geographic areas where children face higher risks of lead exposure in their homes. This 2005 study analyzed existing sources of Washington data regarding housing, population, blood lead testing of children, and soil lead levels. The U.S. Census Bureau and several state agencies provided data for analysis. The study also involved a review of the current academic literature and Centers for Disease Control and Prevention (CDC) studies on childhood lead exposure in homes.

The study yielded the following key findings regarding lead hazards to children in Washington homes:

- **Older homes, lower household incomes, Hispanic ethnicity, and Central Washington residence all correlate with higher blood lead levels in Washington children.** Other risk factors include the location of homes relative to historic orchard lands or lead smelters, particularly Tacoma's ASARCO facility.
- **Homes with higher risk factors for childhood lead exposure are generally located in neighborhoods developed by the mid-20th century.** Suburban areas built more recently tend to have a lower concentration of risk factors.
- **Many of the older town centers with higher priority ratings are clustered in the Puget Sound region, though higher-risk areas are located throughout Washington State.** As shown on the maps, higher priority areas are found in Aberdeen, Bellingham, Ellensburg, Olympia, Seattle, Spokane, Tacoma, the Tri-Cities, Vancouver, Walla Walla, Wenatchee, Yakima, and other population centers around the state. Even very small communities may have significant exposure risk if they contain old homes (particularly if occupied by lower-income residents) or are located on land used for historic apple or pear orchards.
- **Of Washington's 475,000 children under the age of six, an estimated 36,000 (8 percent) live in areas designated the highest priority based on risk factors for childhood lead exposure in homes (Priority 1).** An estimated 93,000 children under age six live in the second-highest priority areas (Priority 2); 175,000 in the third priority areas (Priority 3); and 170,000 in the lowest priority areas (Priority 4).

In addition to these findings, this study presents a series of maps depicting the relative presence of risk for lead exposure to children in homes. The report includes a map of the entire state, as well as 21 local maps of Washington cities.

Results from this study may aid in identifying geographic areas of the state in which to focus future testing, outreach, and control efforts. One limitation of the study is the shortage of blood lead data from a representative sample of children in Washington, compared to other states highlighted in the academic literature. Nevertheless, the method used to designate higher and lower priority areas provides a reasonable and appropriate means of assessing the relative exposure risk in the state, given the limitations in the available data. Further efforts might focus on more detailed site- or child-specific assessments; such new data could help validate the results of this study and guide future public health investments. The Washington State Department of Health estimated that nearly 1 percent of Washington's babies and toddlers (under age three) had elevated blood lead levels in 1999. Though information on comparable age groups is not available from every state, studies suggest a national average of about 2 percent among children under age six, which suggests that the youngest of Washington children may face approximately half the risk of elevated blood levels compared with their peers around the country.

More information about this study and additional copies of this report may be obtained through CTED's lead website: www.cted.wa.gov/lead.

INTRODUCTION AND BACKGROUND

Lead-based paint is the most common source of childhood lead poisoning in the United States. Lead exposure in the home – from paint chips, dust, and other sources – can lead to adverse health effects ranging from anemia and behavior problems to irreversible brain damage or death. Younger children are particularly vulnerable and can experience lifelong health problems and learning disabilities.

The problem of lead-based paint is generally confined to homes built before the 1978 national ban on sales of lead-based residential paint. A large majority of Washington's 2.5 million homes were built prior to 1978; more than 450,000 were built before 1950. Higher lead content of paint in housing built before the mid-20th century, coupled with more time for lead paint to decay, can increase risks in these older homes.

To learn more about this problem in Washington State, the Legislature directed the Department of Community, Trade, and Economic Development (CTED) to conduct a study identifying geographic areas where children face higher risks of lead exposure in their homes. This 2005 study analyzed existing sources of Washington data regarding housing, population, blood lead testing of children, and soil lead levels from the U.S. Census Bureau and several state agencies. The study also involved a review of the current academic literature and Centers for Disease Control and Prevention (CDC) studies on childhood lead exposure in homes.

This information was used to develop a state-specific model to identify expected areas of elevated risk of lead hazards to children in homes. The results are depicted on one statewide map and 21 local maps of Washington cities. The study identified four primary risk factors for lead hazards to children in Washington:

- Age of housing
- Household income
- Hispanic ethnicity
- Residence in Central Washington

This study also considered data on lead smelting and historic use of lead-arsenate pesticides in orchards, but it did not include a detailed examination of sources of potential lead contamination from outside the home. In addition, lack of adequate data prevented consideration of children's exposure to lead in residential drinking water.

Since 1993, the Washington State Department of Health (DOH) has collected data on lead levels from more than 50,000 blood tests on children. However, only about 4 percent of Washington children ever receive a blood lead test. Of those tested, about 2 percent show elevated blood lead levels of 10 micrograms per deciliter (µg/dL) or higher, the current federal threshold of concern.[1] In 1999, DOH used a representative sample of one- to two-year-old children to estimate that nearly 1 percent of Washington's babies and toddlers had elevated lead levels. In comparison, national studies have estimated overall prevalence of elevated blood lead levels among one- to five-year-old children at approximately 2 percent, with prevalence in some states as high as 15 percent in the late 1990s.[2] Although Washington is not among the worst states for childhood lead poisoning, lead still poses a significant health hazard to children in many areas of the state.

1 Most experts agree that blood lead levels above 10 µg/dL are undesirable based on population studies. Some scientists would prefer an even more stringent guideline. Effects on individuals are variable and may not be evident at 10 µg/dL.

2 Centers for Disease Control and Prevention, 2005. "Children's Blood Lead Levels in the United States." http://www.cdc.gov/nceh/lead/research/kidsBLL.htm. Accessed November 23, 2005.

METHODOLOGY

The findings and maps presented in this report describe areas of the state with a relatively high presence of risk factors for childhood lead exposure in homes. The project team and its academic partners used the following methodology to develop the findings and produce the maps presented in this report;

1. **Review the existing scientific and government literature on risk factors for childhood lead exposure in homes.** The consultant reviewed over 20 articles from scholarly journals, including papers from researchers at the U.S. Department of Housing and Urban Development (HUD),[3] the Centers for Disease Control and Prevention,[4] Duke University,[5] and Dartmouth University.[6] University of Washington faculty assisted in this review and assessment of the existing literature.

2. **Compile relevant data sets in Washington.** Based on risk factors identified in the literature, the consultant compiled Washington-specific data sets on blood lead levels in children, soil lead levels, housing and demographics, and other factors such as the extent of soil contamination from ASARCO's former lead smelter in Tacoma and former orchard areas where lead-arsenate pesticides were likely used. A key data set was the Department of Health's Childhood Blood Lead Registry, which includes over 50,000 blood lead tests on Washington children extending back to 1993. Tests from over 7,000 children since 2000 were selected from this data set as being the most representative samples for this study.[7]

3. **Conduct statistical analysis to determine relationships between risk factors and blood lead levels among children in Washington.** The Children's Environmental Health Initiative (CEHI) at Duke University has performed extensive work modeling childhood lead exposure risks in communities across the United States.[8] For this project, CEHI staff and staff at the Washington State Department of Health (DOH) analyzed the DOH data set of children's blood lead levels along with U.S. Census data to determine which housing and socioeconomic variables were strong predictors of higher blood lead levels. The researchers performed a regression analysis, which is a statistical method designed to determine relationships and trends in existing data, and to predict the number or level of one variable (e.g., blood lead levels) based on the corresponding numbers or levels of other variables (e.g., age of housing or socioeconomic status). DOH's Childhood Blood Lead Registry shows blood lead test results by census tract, so the analysis was conducted at that level. (A census tract typically contains an average of about 4,500 residents.)

   The researchers identified several risk factors that showed statistically significant relationships with blood lead levels in Washington children. In particular, older housing, lower median incomes, Hispanic ethnicity, and Central Washington residence all helped predict higher blood lead levels. Based on these findings, the DOH and CEHI staff recommended a model that uses weighted risk factors (based on U.S. Census data and derived from the regression analysis) to predict a risk index for each census tract and identify higher priority areas throughout the state. The assessment is relative rather than absolute in that it identifies areas with higher and lower risk relative to each other (but does not quantify how high the risk is in any area), due to limitations in the available data.

   The concept of "weighted risk factors" means that each risk factor (e.g., age of housing, median income) was assigned a relative "weight" (termed a coefficient) that determines its relative impact on each census tract's risk index.

4. **Produce maps showing the relative prevalence of the identified risk factors for childhood lead exposure in homes.** The consultant used geographic information system (GIS) software to apply the statistical model to communities throughout Washington. A statistical method was used to classify each census tract into one of four priority ratings based on natural break-points in the data, and the map was colored from light yellow to deep orange accordingly.[9]

   Please note that the priority ratings and colors are estimates and are based on a model that applies the information from DOH's existing blood lead data for children, collected in about 40 percent of the state's census tracts, to the entire state. Results in any given tract, however, may not reflect actual blood lead levels in that area's children. More detailed assessments of individual housing units or increased blood testing of children could help strengthen the relative risk exposure findings identified in this study.

   Note also that in sparsely populated areas of the state, census tracts become much larger and may contain broad areas with few or no residents, such as National Forests, farmlands, or mountains. Though at-risk children living in these tracts are clearly a concern, shading

the entire tract a dark color based on the priority status of a small population center it contains could place undue emphasis on the large surrounding areas where few people live. Accordingly, a stippled pattern (see map keys) is used to indicate the priority in these low-population tracts to avoid suggesting the inaccurate conclusion that rural areas have the most risk from lead. The stippled pattern is applied to census tracts that contain less than the state's average housing density of 36.8 housing units per square mile. Although these 183 very rural census tracts comprise the majority of Washington's land area, they house only 10 percent of Washington's children.

5. **Overlay other relevant data for potential lead sources on selected maps.** Where available, other data pertaining to lead exposure were included on maps of selected communities. Data from the Tacoma Smelter Plume studies[10] were added to the Tacoma and Seattle area maps; soil lead data provided by the Washington State Department of Ecology was included on the Wenatchee area map, to reflect the likely historical influence of lead-arsenate pesticides in that region; and an estimation of past orchards in the Yakima area was included because of likely use of lead-arsenate pesticides. A method to consider the influence of leaded gasoline emissions near major roadways was also considered but ultimately discarded due to lack of available data and studies from other areas showing that soil lead levels from gasoline emissions decrease dramatically within 100 feet of major roadways.

This methodology was developed by the consultant team, CTED, DOH, and faculty and staff at both Duke University and the University of Washington. These parties consider this approach to be an efficient and practical method for assessing the relative lead exposure risk in Washington communities based on both child lead testing in Washington and previous studies of lead hazards in housing conducted elsewhere.

The methodology does have limitations. In particular, the data included in DOH's Childhood Blood Lead Registry are limited, compared to the extent of data available in some other states. Also, most data included in the DOH database were not collected using random sampling or other methods designed to assure representative results. As a result of the model used for this study, each census tract received a single rating based on the average profile of the tract, and so the entire census tract area received the same rating (and color on the map), even if individual homes within that neighborhood may actually have a lower or higher presence of risk factors.

The data selected and statistical analysis methods used were specifically chosen by DOH and CEHI staff at Duke to make the best use of the available data. Faculty members at the University of Washington's School of Public Health reviewed both the approach and the resulting model and found them to provide a reasonable and appropriate means of assessing the relative exposure risk in Washington.[11]

Although none of the maps should be used as a substitute for a site- or child-specific assessment, they can be used to develop an understanding of where the expected risk factors for childhood lead exposure in homes are greatest. For additional statistical notes about the model used, please see the appendix at the end of this document.

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3 Jacobs, D.E., et al., 2002. The Prevalence of Lead-based Paint Hazards in U.S. Housing. *Env. Health Perspectives* 110: 947-953.

4 Curtis, G.B., et al., 2004. *Using GIS to Assess and Direct Childhood Lead Poisoning Prevention: Guidance for State and Local Childhood Lead Poisoning Prevention Programs*. Centers for Disease Control and Prevention, Childhood Lead Poisoning Prevention Program.

5 Miranda, M.L., D.C. Dolinoy, and M.A. Overstreet, 2002. Mapping for Prevention: GIS Models for Directing Childhood Lead Poisoning Prevention Programs. *Env. Health Perspectives* 110: 947-953.

6 Sargent, J.D., et al., 1997. Census Tract Analysis of Lead Exposure in Rhode Island Children. *Environmental Research* 74: 159–168.

7 See Appendix for further discussion of the data analysis.

8 CEHI is a research, education, and outreach program committed to fostering environments where all children can prosper. CEHI is based within the Nicholas School of the Environment at Duke University.

9 This statistical classification method, termed "Jenks natural breaks," was the same method used in the Duke group's landmark paper on this subject. Miranda, M.L., D.C. Dolinoy, and M.A. Overstreet, 2002. Mapping for Prevention: GIS Models for Directing Childhood Lead Poisoning Prevention Programs. *Env. Health Perspectives* 110: 947-953. In addition, University of Washington researchers Dr. Michael Yost and Dr. Jaya Ramaprasad performed simulations to validate the reliability of the model at assigning Census tracts to each of the four priority levels.

10 The Washington State Department of Ecology has assembled information about the Tacoma Smelter Plume project on a website, http://www.ecy.wa.gov/programs/tcp/sites/tacoma_smelter/ts_hp.htm.

11 Dr. Michael Yost and Dr. Jaya Ramaprasad reviewed the model and performed statistical reliability tests.

OVERALL RESULTS

The statistical analysis of the Washington State Department of Health's Childhood Blood Lead Registry database, conducted by the Department of Health and Duke University's Children's Environmental Health Initiative, identified statistically significant relationships between several risk factors and blood lead levels in Washington children. Although the analysis cannot determine actual lead sources or specific ways that lead might be entering into the bodies of individual children, it can be used to predict areas in the state with a higher presence of risk factors for childhood lead poisoning: areas where prevention efforts are likely to be most beneficial. Variables found to be significant and used in the model include:

- **Age of housing.** The statistical analysis found a strong relationship between the percentage of older homes in an area and the blood lead levels of children in those areas. In particular, the researchers found a strong correlation between the percent of homes built before 1940 and higher blood lead levels.
- **Income.** The analysis found that neighborhoods with lower median incomes tended to have higher blood lead levels than higher-income neighborhoods, even when controlling for other factors. Median house value was also included in the model as a related variable. Homes occupied by lower-income residents may be more likely to be in poor condition and contain peeling or deteriorating paint.
- **Hispanic ethnicity.** Hispanic ethnicity was also identified as a predictive risk factor. Although the reason for this relationship is unknown, one possible explanation is that people of Hispanic ethnicity in Washington may be more likely to work in agriculture, perhaps on lands that contain historic lead-arsenate pesticide residues. Adult farm workers could expose their children through lead-containing dust present on their clothing and shoes. In addition, the Department of Health has identified some Mexican candy and folk remedies as possible additional exposure sources.
- **Central Washington residence.** Residence in a Central Washington county was identified as a statistically significant risk factor.[12] The reason for this relationship is unknown, but it may relate to the greater extent of historic lead-arsenate pesticide use in Central Washington compared to other parts of the state.

The estimation model developed for this study classifies census tracts throughout Washington into four priority levels: 1 (higher priority) through 4 (lower priority). Priority 1 areas represent neighborhoods with the highest concentration of risk factors – generally neighborhoods with older homes and with low to moderate median household incomes, although neighborhoods in Central Washington or those with a high fraction of Hispanic residents may receive a Priority 1 rating, even if homes are not as old or incomes as low as in other high priority areas. In contrast, Priority 4 areas have a low incidence of risk factors and generally have few older homes.

Based on review of the resulting maps and data, the following overall key findings emerge:

- **Higher priority areas tend to cluster in or near the center of older towns.** In contrast, suburban areas built more recently tend to be lower priority areas. Note the "bull's-eye" effect in several towns where the center is Priority 1, with expanding rings of lower priority areas surrounding the town. (The Spokane map on page 29 provides a clear example.)
- **Nearly 10 percent of all Washington children under age six are found in areas designated as the highest priority (Priority 1) based on risk factors for childhood lead exposure in homes.** The number of children with elevated blood lead levels (greater than 10 µg/dL) is likely higher in these areas than in lower priority areas.
- **Many of the older town centers with Priority 1 ratings are clustered in the Puget Sound region, though higher-risk areas are located throughout Washington State.** Priority 1 areas are found in Aberdeen, Bellingham, Ellensburg, Olympia, Seattle, Spokane, Tacoma, the Tri-Cities, Vancouver, Walla Walla, Wenatchee, Yakima, and other population centers around the state. Small communities not represented on the maps may still have significant exposure risk if they contain old homes or are located on land historically used for apple or pear orchards.

Please see the statewide map on page 8 for a depiction of the relative presence of risk factors for childhood lead exposure in homes throughout Washington. Close-up maps for many population centers throughout the state can be found on pages 9-29.

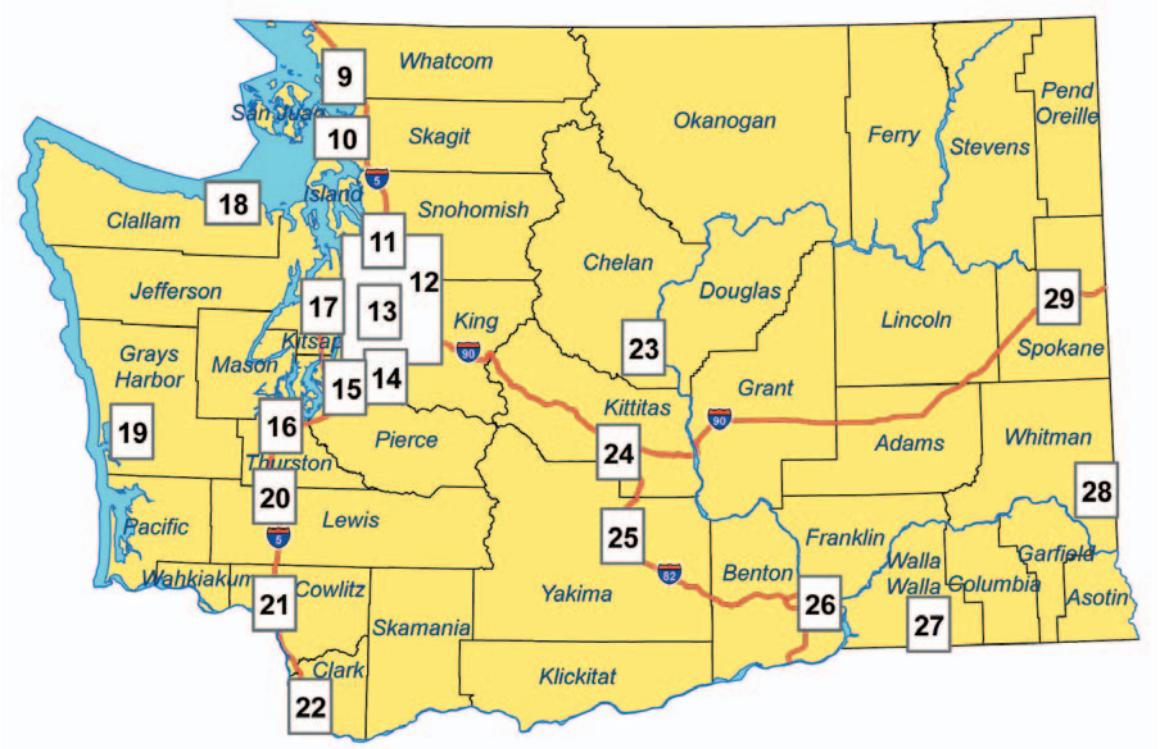
12 Counties identified as Central Washington include Adams, Benton, Chelan, Douglas, Franklin, Grant, Kittitas, Klickitat, Okanogan, Walla Walla, and Yakima.

LOCAL RESULTS AND MAP

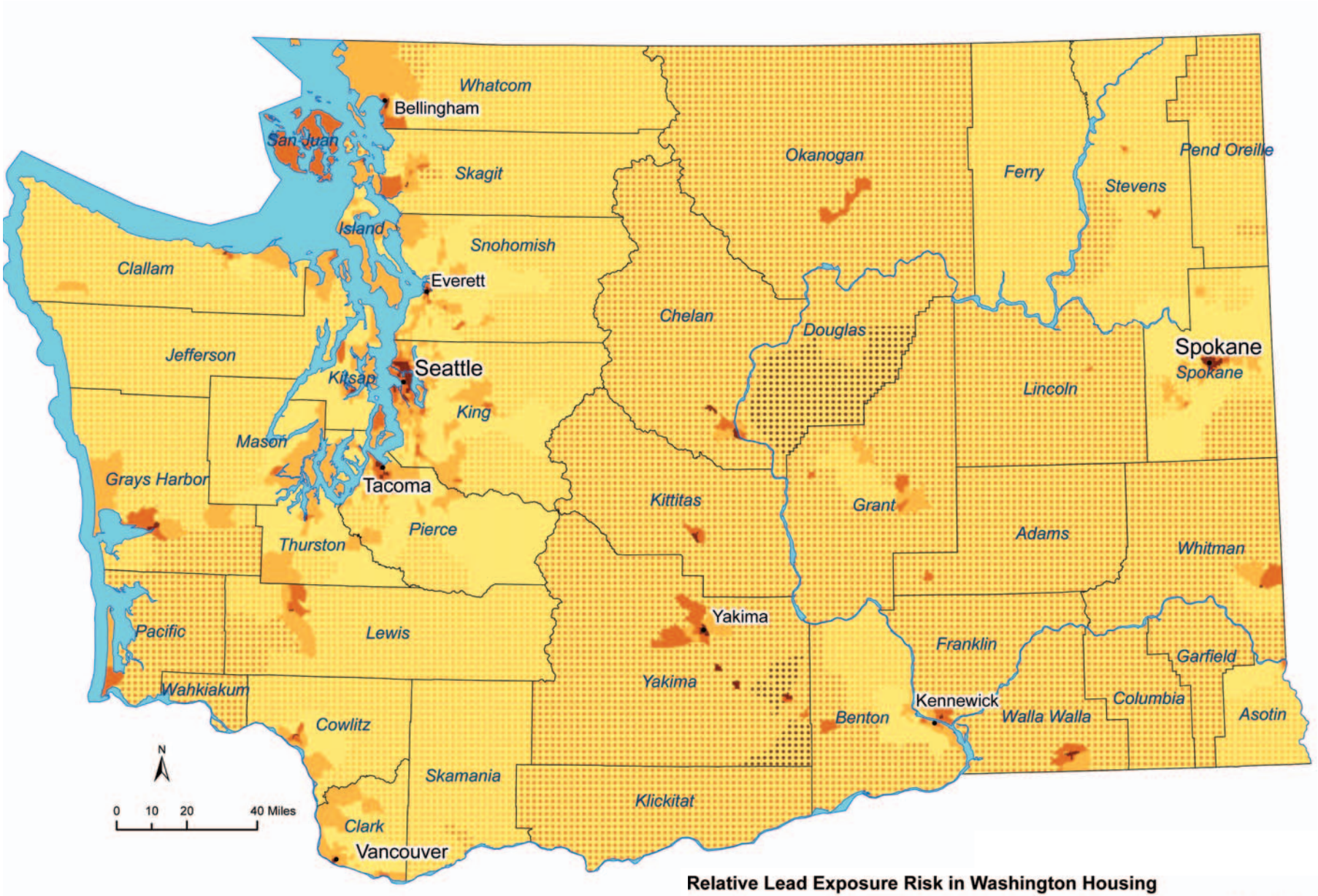
A statewide map of priority areas can be found on page 8. This section includes 21 maps of cities and towns throughout Washington. The regions selected are metropolitan areas with at least 50,000 people plus additional areas with a concentration of Priority 1 neighborhoods. Please note that detailed maps could not be developed for every city or county in Washington. Maps were selected to include the vast majority of Washington homes as well as to provide an overview of areas of risk across the state.

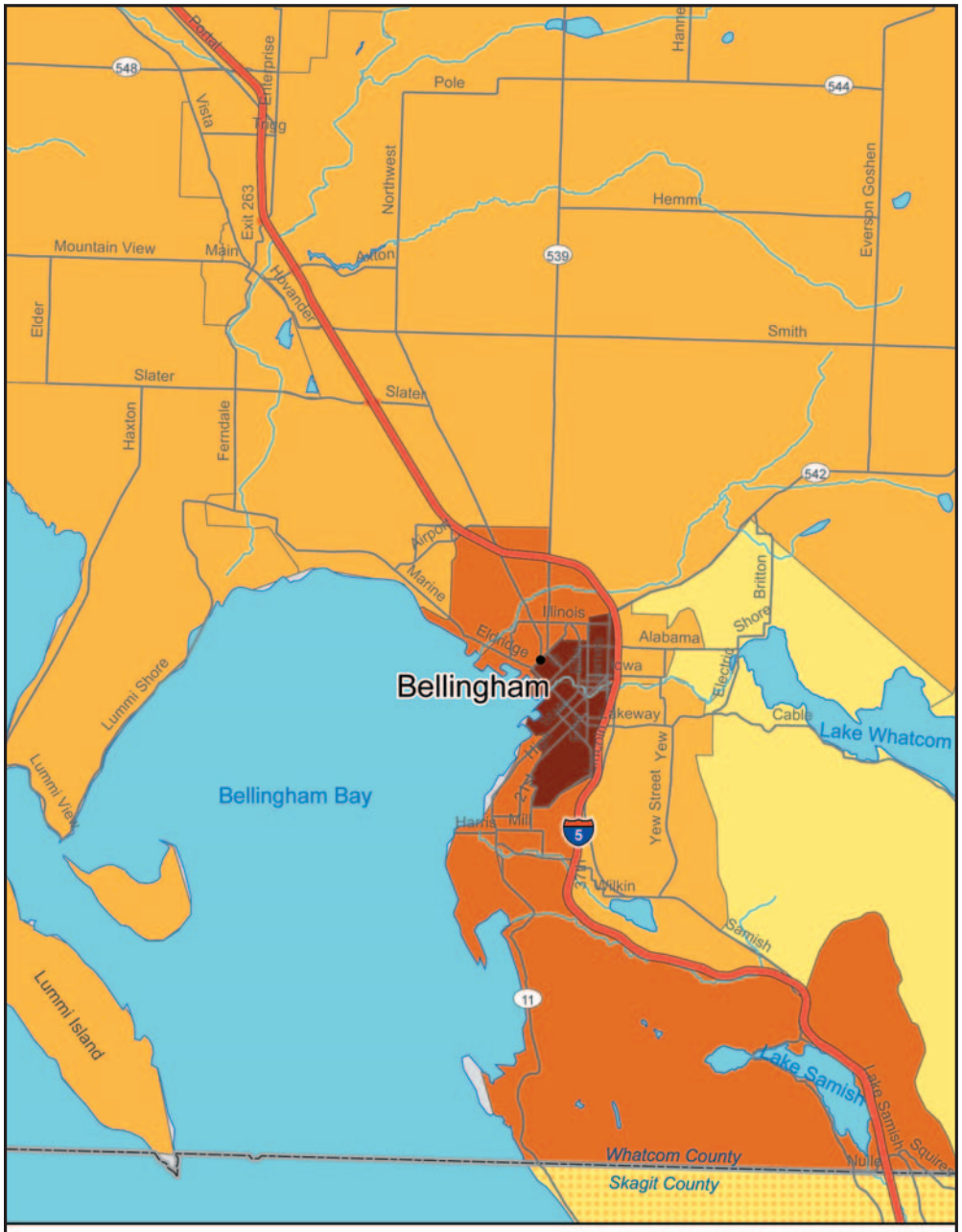
Maps are presented in approximate counterclockwise order beginning in northwest Washington (Bellingham area) and ending in northeast Washington (Spokane area). Maps are presented in the following order: Bellingham, Anacortes-Mount Vernon, Everett, Greater Seattle area (including a more detailed map for Seattle), Kent-Enumclaw, Tacoma, Olympia, Bremerton, Port Angeles-Sequim, Aberdeen-Hoquiam, Centralia-Chehalis, Longview-Kelso, Vancouver, Wenatchee, Ellensburg, Yakima, Tri-Cities, Walla Walla, Pullman, and Spokane.

INDEX OF LOCAL MAPS, BY PAGE NUMBER



STATEWIDE MAP





Relative Lead Exposure Risk in Washington Housing: Bellingham

- Priority 1 (higher)
- Priority 2
- Priority 3
- Priority 4 (lower)

Stippled pattern indicates priority level in census tracts with housing density below the statewide average of 36.8 housing units per square mile.

Results are estimates only and may not reflect actual blood lead measurements in Washington children.

This figure was originally produced in color. Reproduction in black and white may result in loss of information.

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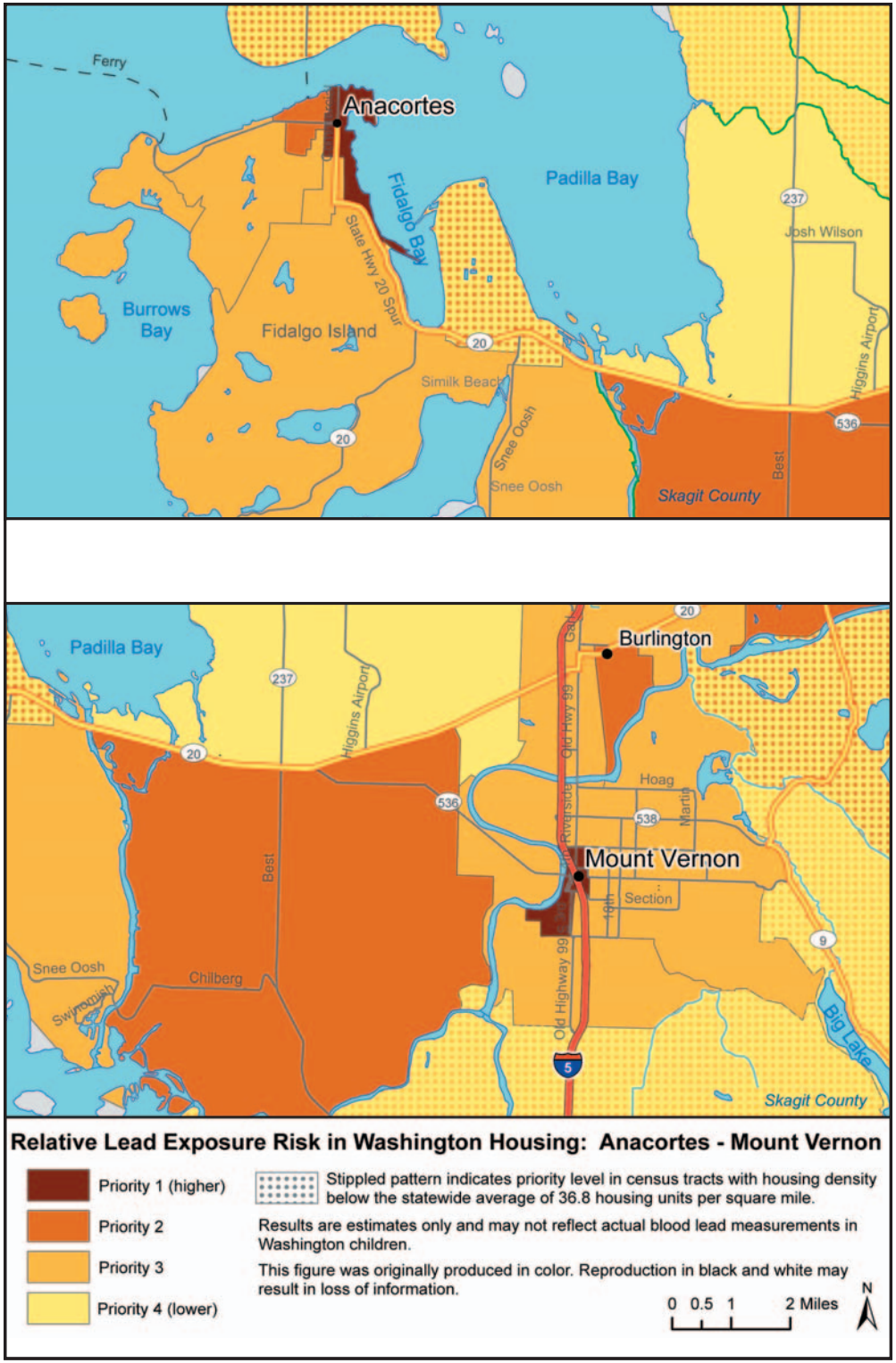
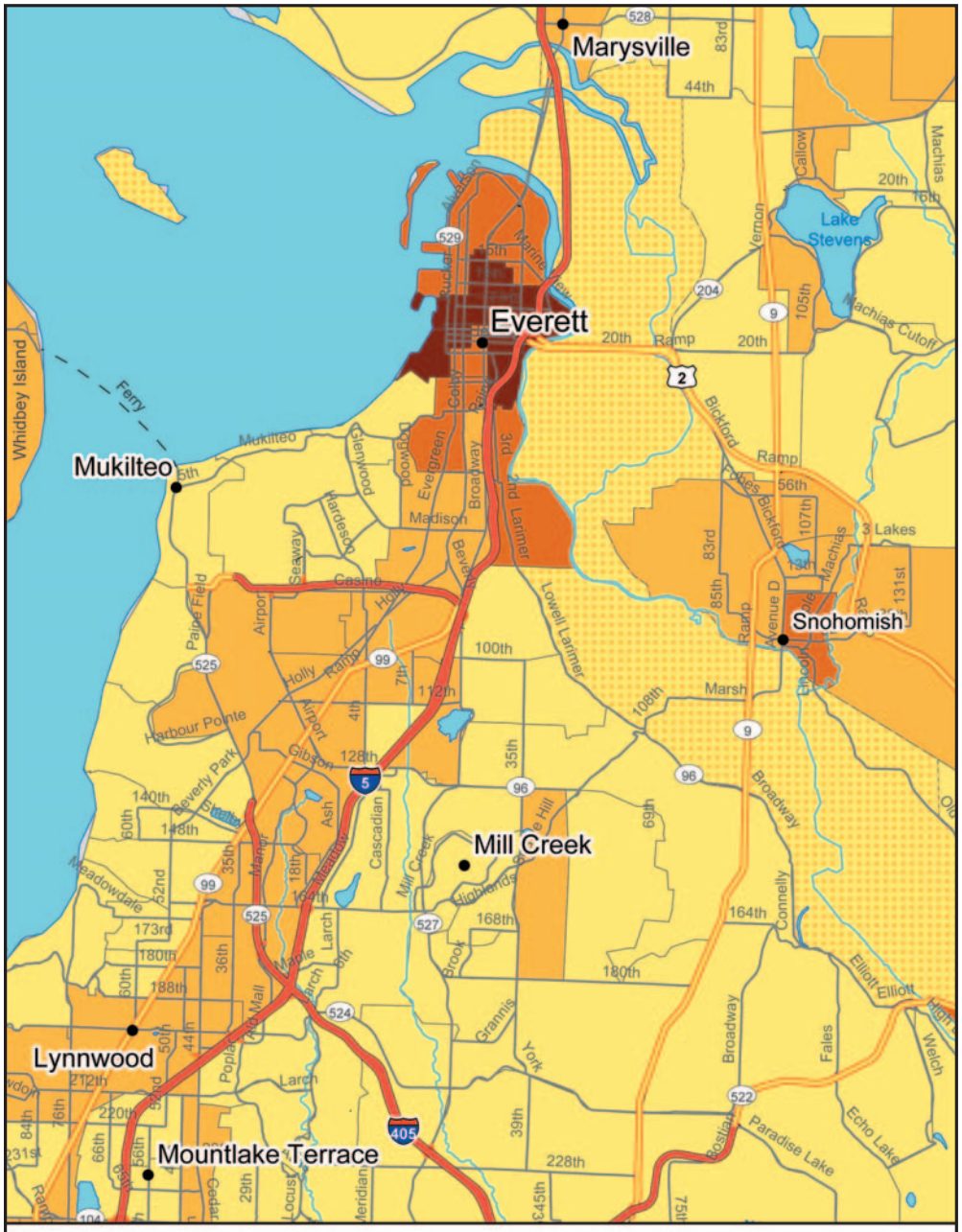
BELLINGHAM

The higher priority areas (Priorities 1 and 2) in Bellingham are concentrated in the center of the town, west of Interstate 5.

ANACORTES – MOUNT VERNON

Both Anacortes and Mount Vernon are estimated to have small Priority 1 areas in and surrounding the original downtowns. Note that the outskirts of Mount Vernon, with generally newer homes, is an area estimated to be mostly lower priority (Priority 3).





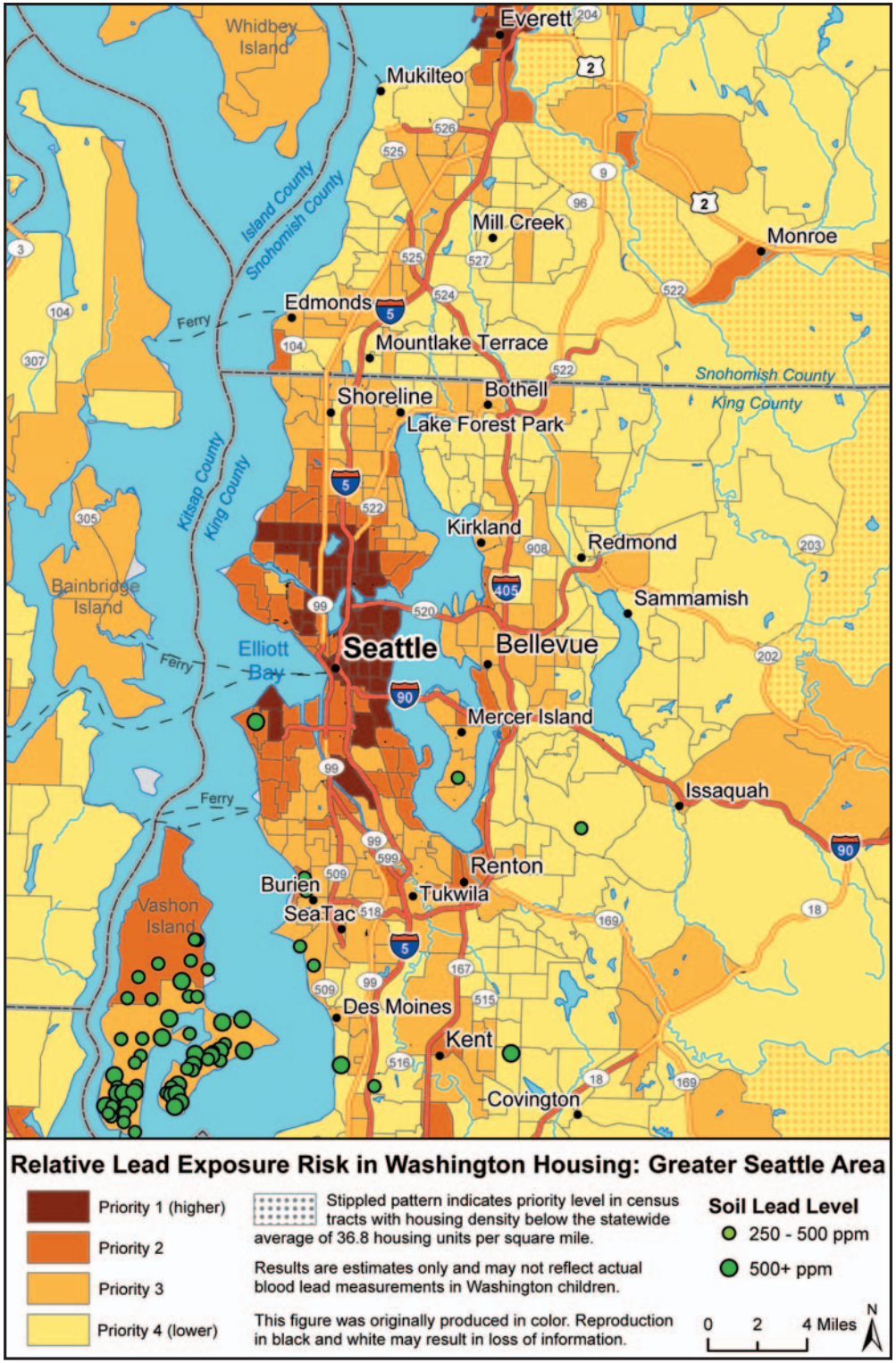
EVERETT

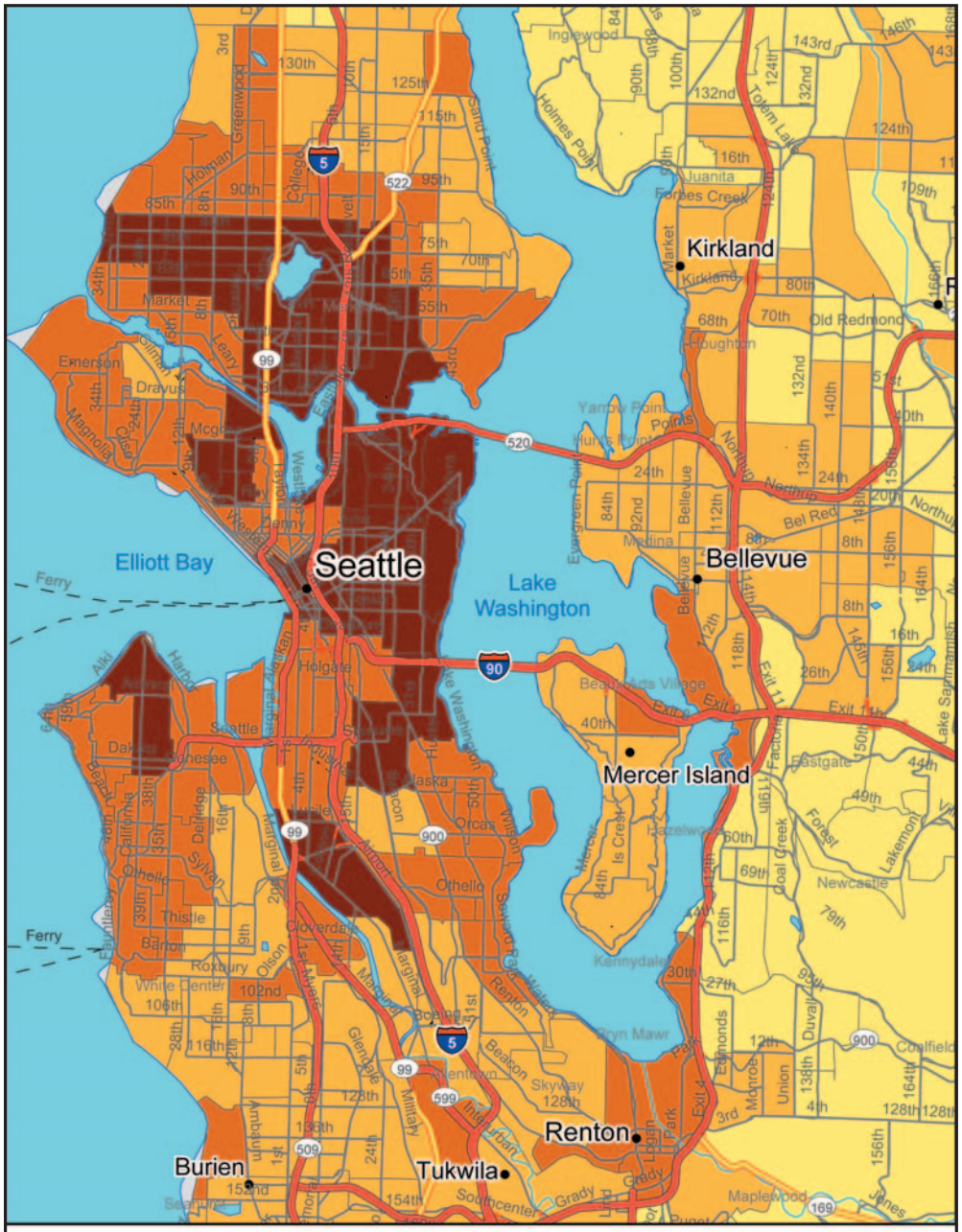
Unlike the newer cities between Everett and Seattle, nearly all of Everett received a higher priority rating (Priority 1 or 2), with homes in or near the city center receiving a Priority 1 rating. The estimation model indicates that the nearby areas of Mukilteo and Marysville are generally lower priority, although these areas may include pockets of older homes and higher risk factors. The town of Snohomish, approximately 10 miles southeast of Everett, includes a number of older homes and received a Priority 2 rating.

GREATER SEATTLE AREA

The greater Seattle area contains both dense areas of Priority 1 neighborhoods and large expanses of suburban development with a very low presence of risk factors for childhood lead exposure in homes.

Note that the priority ratings assigned to the Seattle area were developed based on housing and socioeconomic factors, using the same estimation model as the rest of the state. However, a contributor to soil lead levels in southwest King County is the influence of the former ASARCO lead smelter near Tacoma. Soil samples collected as part of the Tacoma Smelter Plume studies are plotted over the priority ratings on the Seattle region map and help indicate the extent and magnitude of the former smelter's influence on soil lead levels.[13] For more information on the smelter studies in the Tacoma region (including southwest King County), see the description of the Tacoma map.





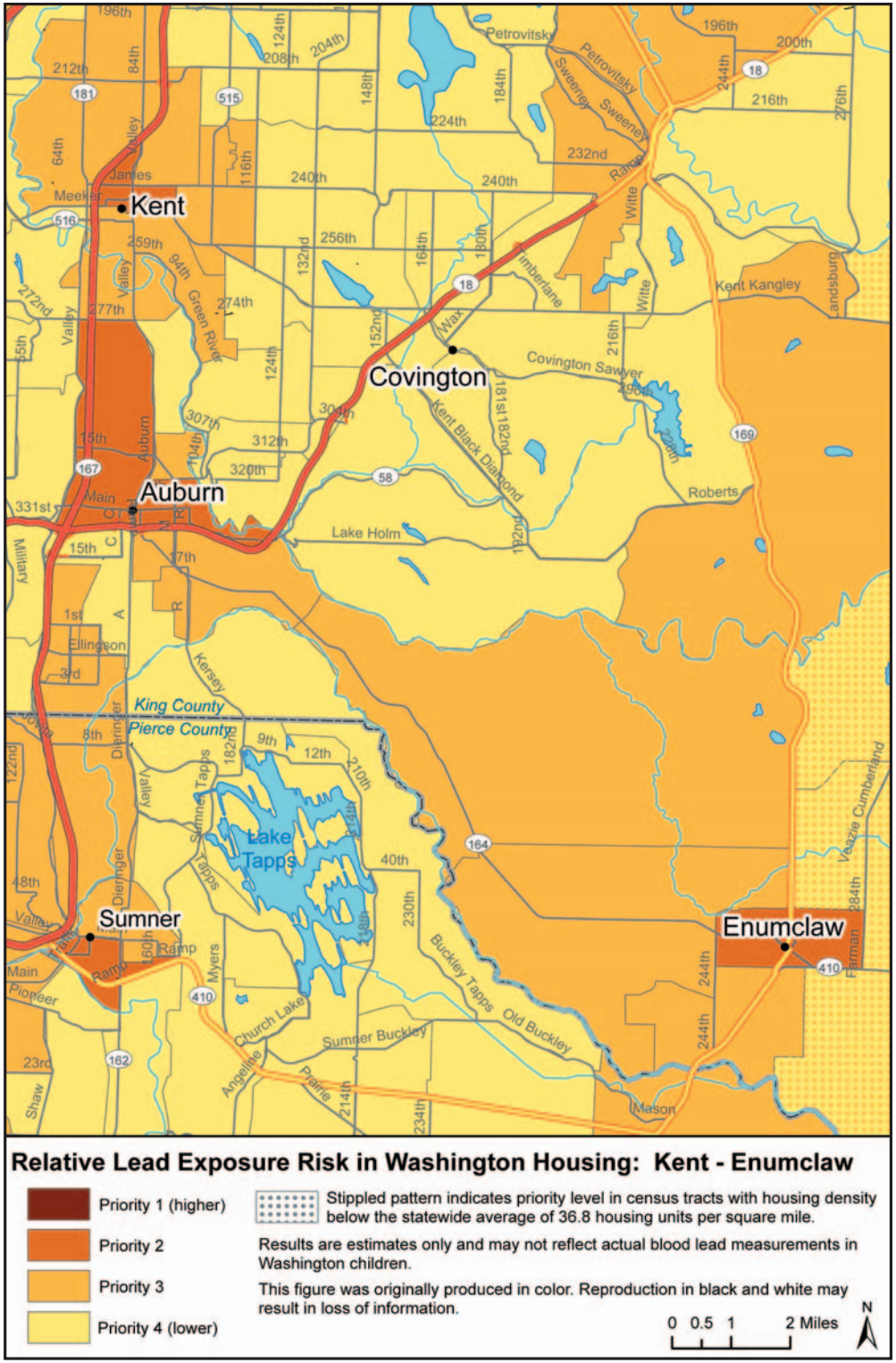
SEATTLE

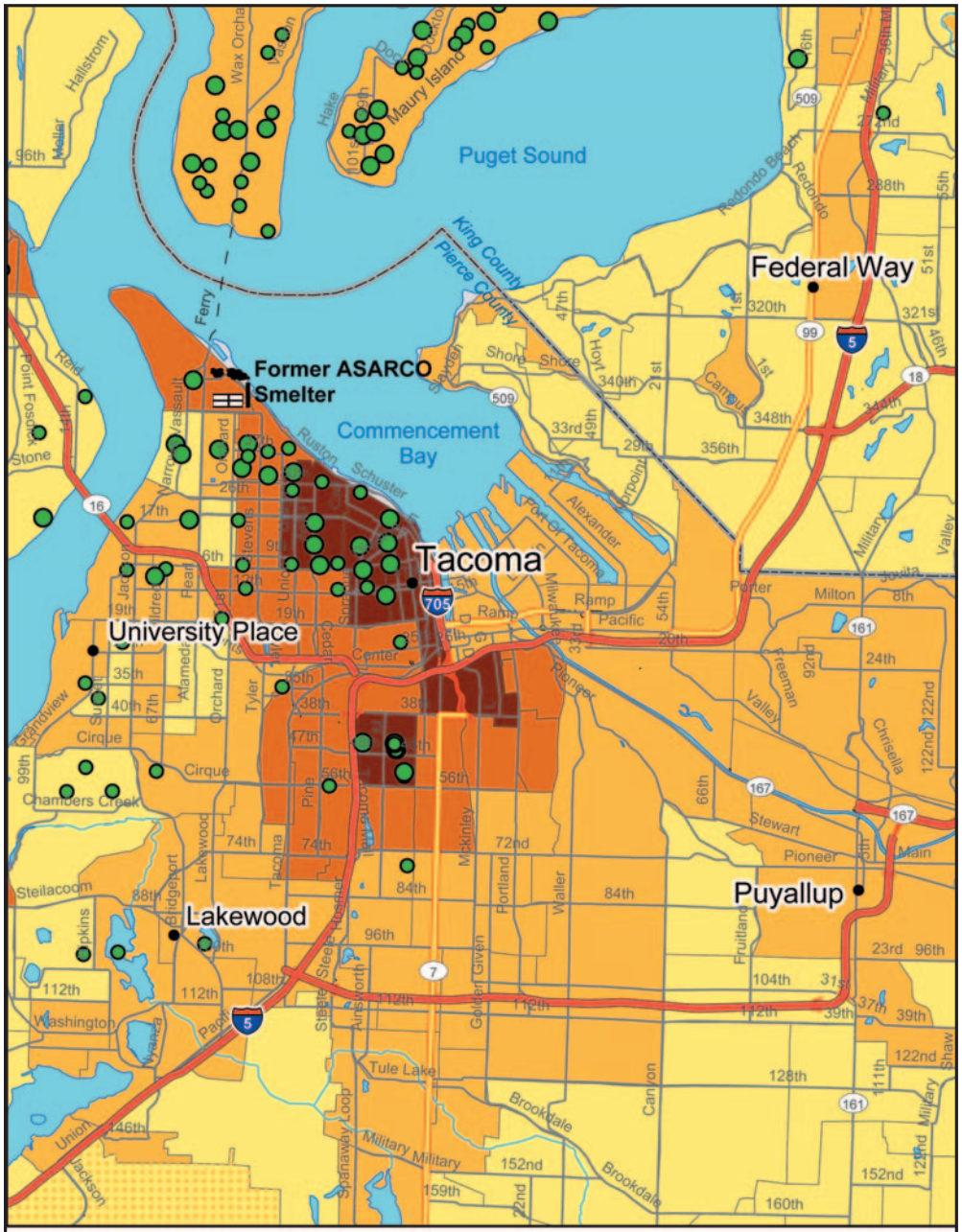
Seattle itself contains numerous neighborhoods that received a Priority 1 rating, due largely to the high percentage of homes built in the first half of the 20th century. Particular neighborhoods with higher priority ratings include, but are not limited to Georgetown, portions of West Seattle, the Central District, Madrona, First Hill, Capitol Hill, Queen Anne, the University District, Wallingford, Green Lake, and Ballard. Suburban Seattle generally received lower priority ratings due to generally newer homes.

13 The maximum value recorded at each site is plotted on the map.

KENT - ENUMCLAW

The older city centers of Auburn, Enumclaw, Kent, and Sumner all contain concentrations of older homes that lead to higher Priority 2 ratings. More rural areas of south King County and northeast Pierce County generally received lower priority ratings.





TACOMA

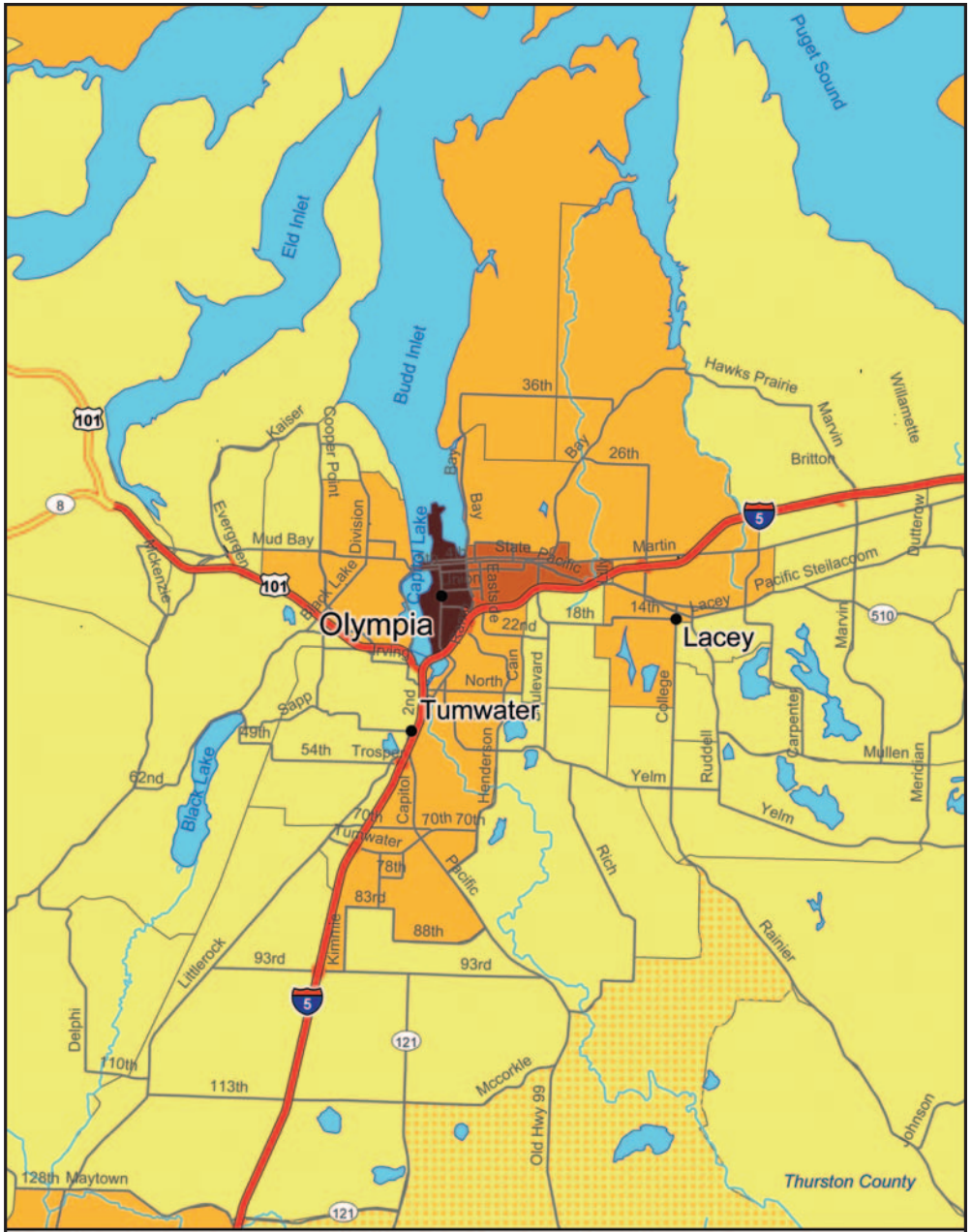
Much of Tacoma received a Priority 1 or 2 rating, due largely to the age of homes. The more recently developed communities of Lakewood and University Place received lower priority ratings.

Note that the priority ratings assigned to the Tacoma area were developed based on housing and socioeconomic factors, using the same estimation model as the rest of the state. However, a contributor to soil lead levels in Tacoma is the influence of the former ASARCO lead smelter. Studies of soil lead levels in the Tacoma area, including the southern end of Vashon/Maury Island, have indicated numerous areas with soil lead levels above 500 parts per million (ppm), although the smelter fallout has not been linked to lead poisoning in children. (The state standard for lead-contaminated soil is 250 ppm.) Soil samples collected as part of the Tacoma Smelter Plume studies are plotted over Tacoma's priority ratings and help indicate the extent and magnitude of the former smelter's influence on soil lead levels in the Tacoma region.[14]

14 The maximum value recorded at each site is plotted on the map.

OLYMPIA

A large portion of Olympia – the denser neighborhoods north of Interstate 5 and east of Capitol Lake, including the Capitol area – received a Priority 1 rating, while other neighborhoods generally received Priority 2 or 3 ratings. Most of greater Olympia, including the communities of Lacey and Tumwater, received lower ratings of Priority 3 or 4.



Relative Lead Exposure Risk in Washington Housing: Olympia

- Priority 1 (higher)
- Priority 2
- Priority 3
- Priority 4 (lower)

Stippled pattern indicates priority level in census tracts with housing density below the statewide average of 36.8 housing units per square mile.

Results are estimates only and may not reflect actual blood lead measurements in Washington children.

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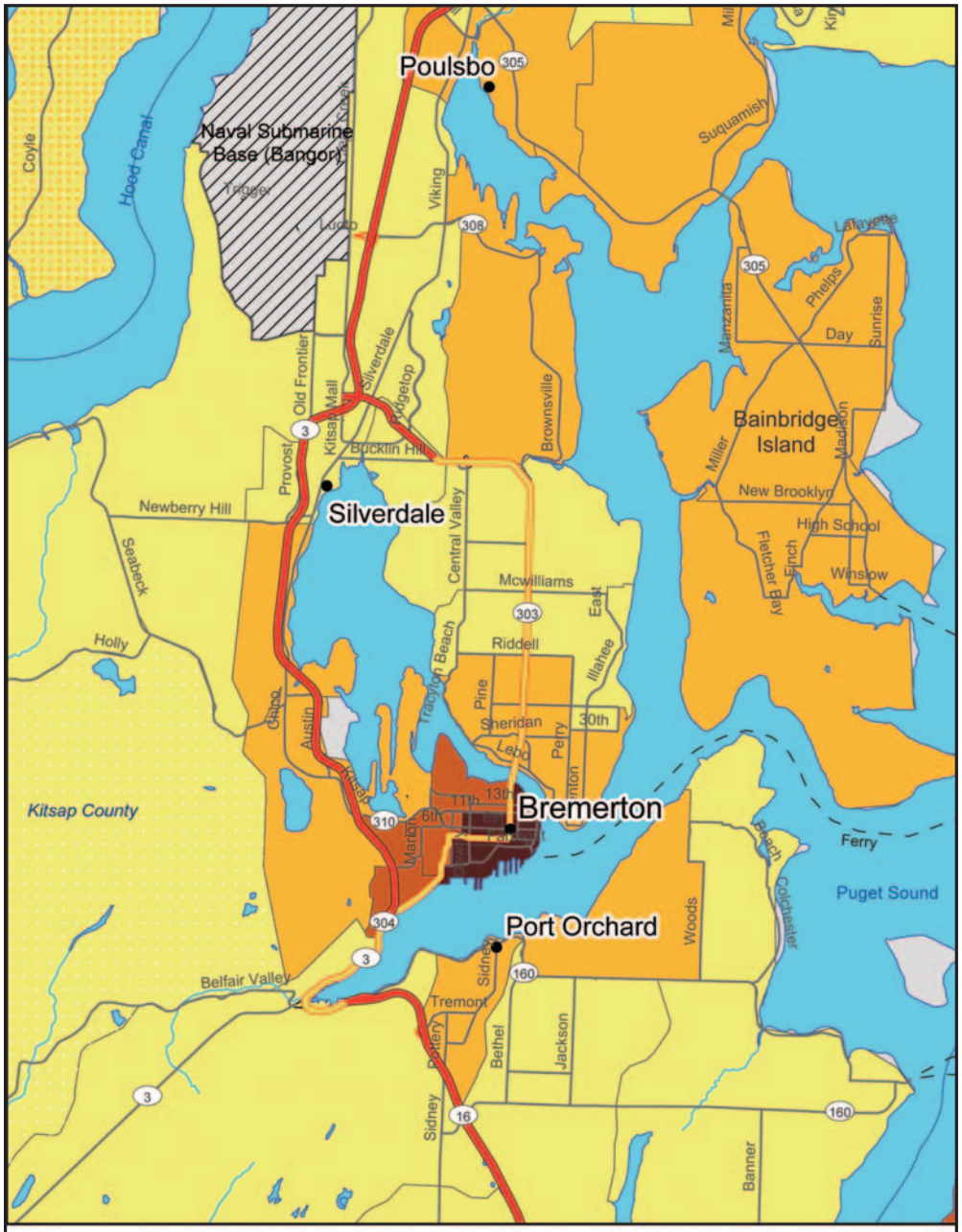

Relative Lead Exposure Risk in Washington Housing: Bremerton

- Priority 1 (higher)
- Priority 2
- Priority 3
- Priority 4 (lower)

Stippled pattern indicates priority level in census tracts with housing density below the statewide average of 36.8 housing units per square mile.

Results are estimates only and may not reflect actual blood lead measurements in Washington children.

This figure was originally produced in color. Reproduction in black and white may result in loss of information.

0 0.5 1 2 Miles

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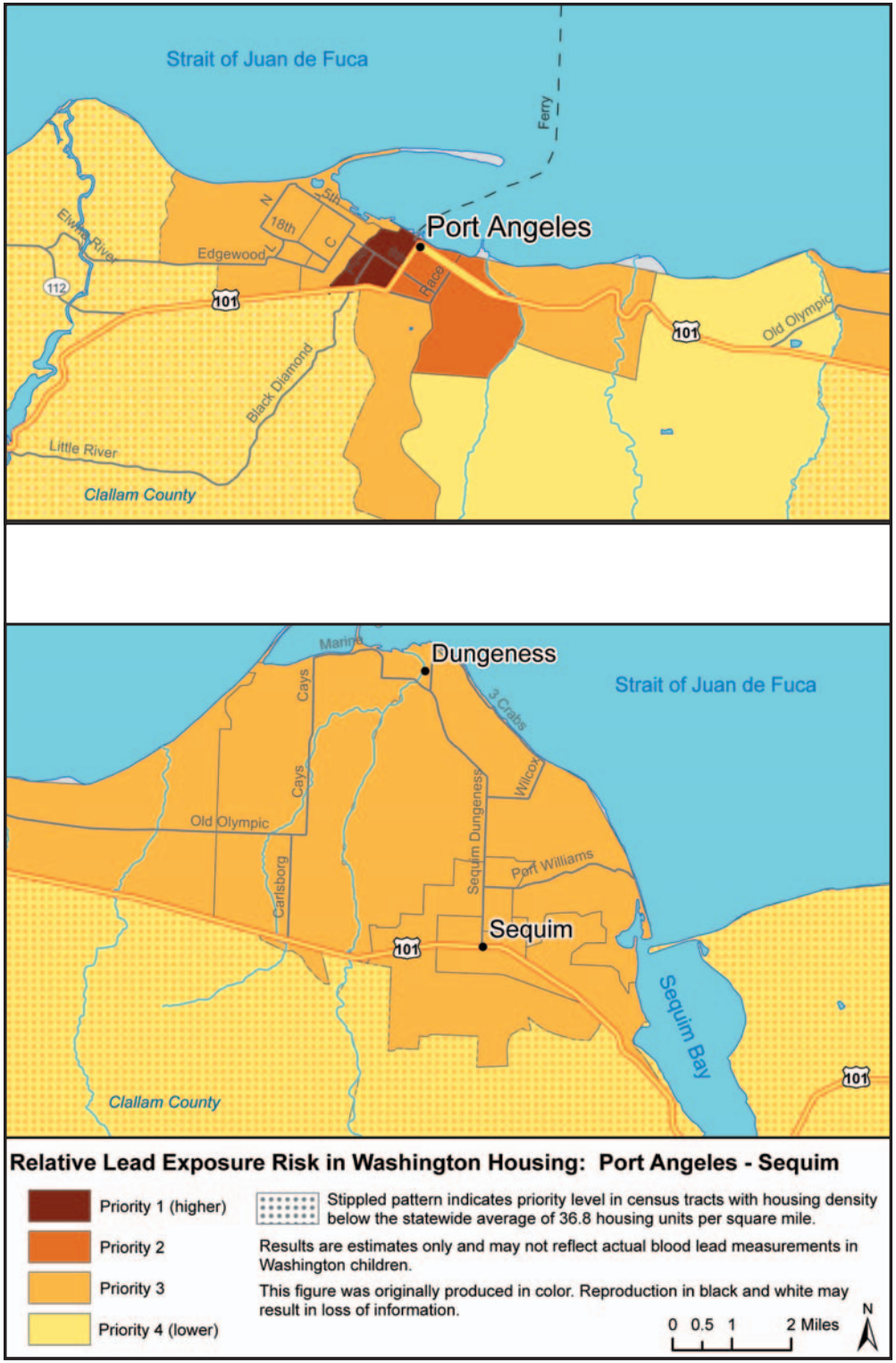
BREMERTON

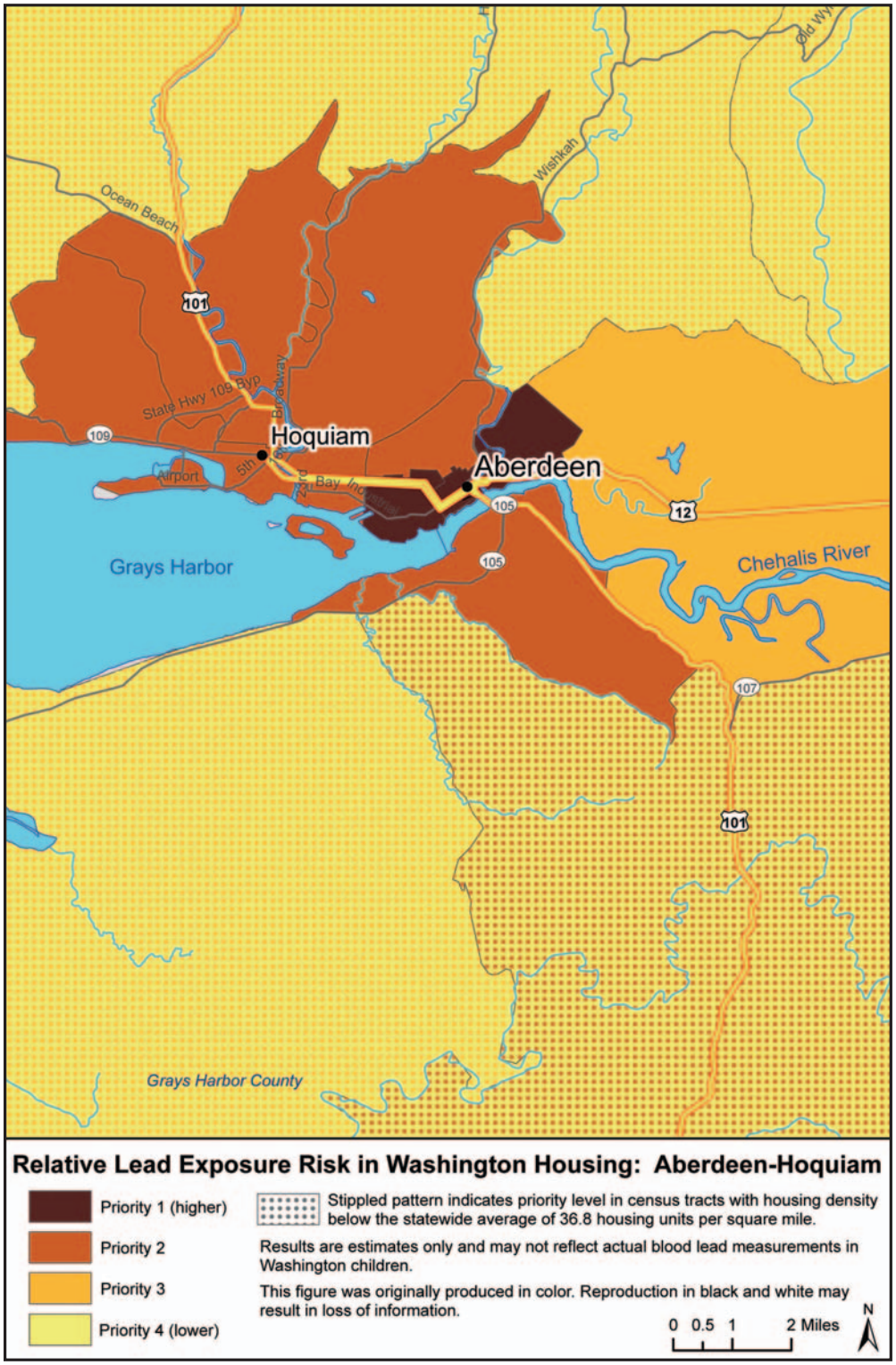
Like most older cities in Washington, neighborhoods in and around Bremerton's city center received Priority 1 and 2 ratings, while most outlying neighborhoods received Priority 3 or 4 ratings. Other nearby communities received lower priority ratings.

PORT ANGELES - SEQUIM

A portion of central Port Angeles received a Priority 1 rating.

The Sequim area received a Priority 2 rating.



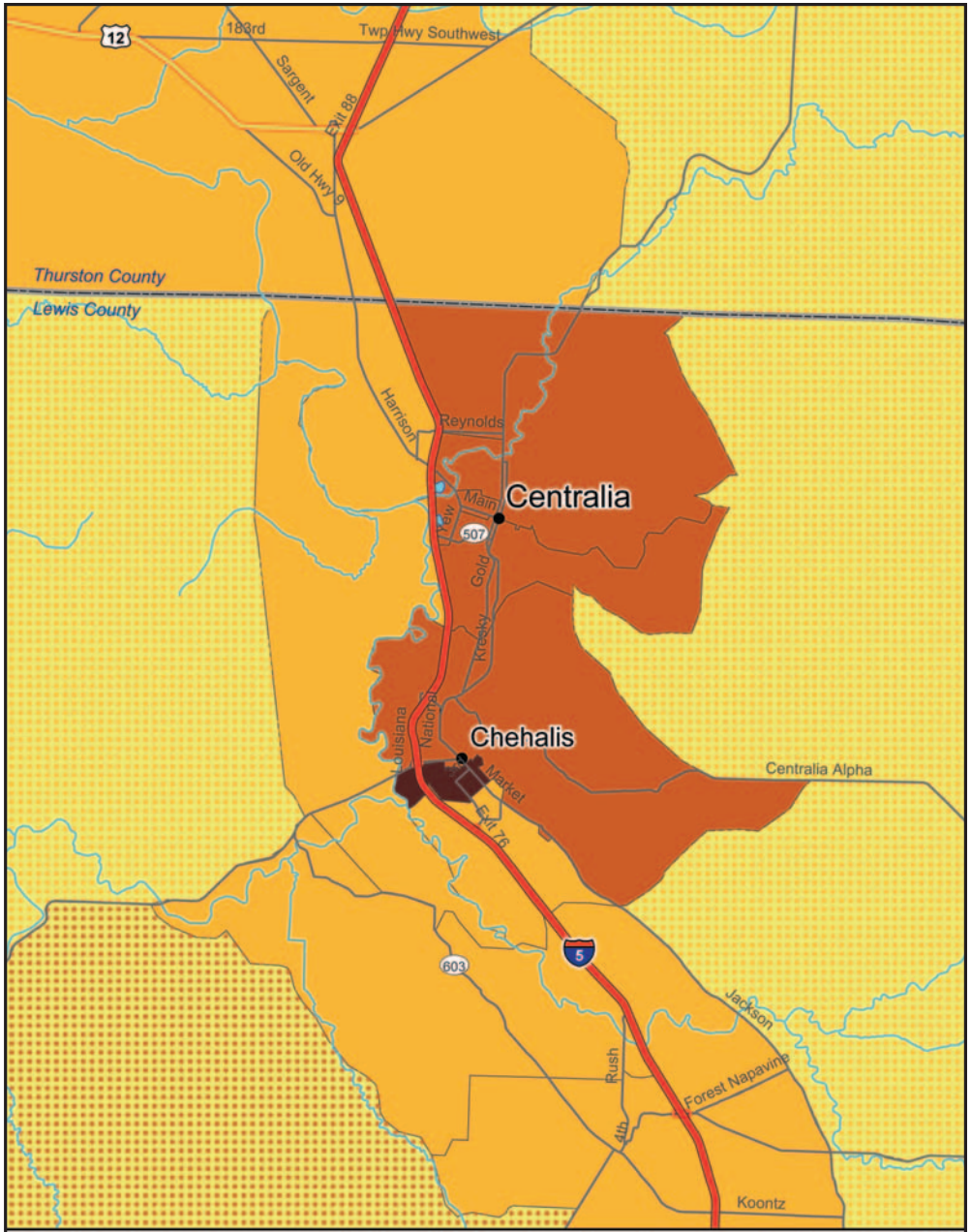


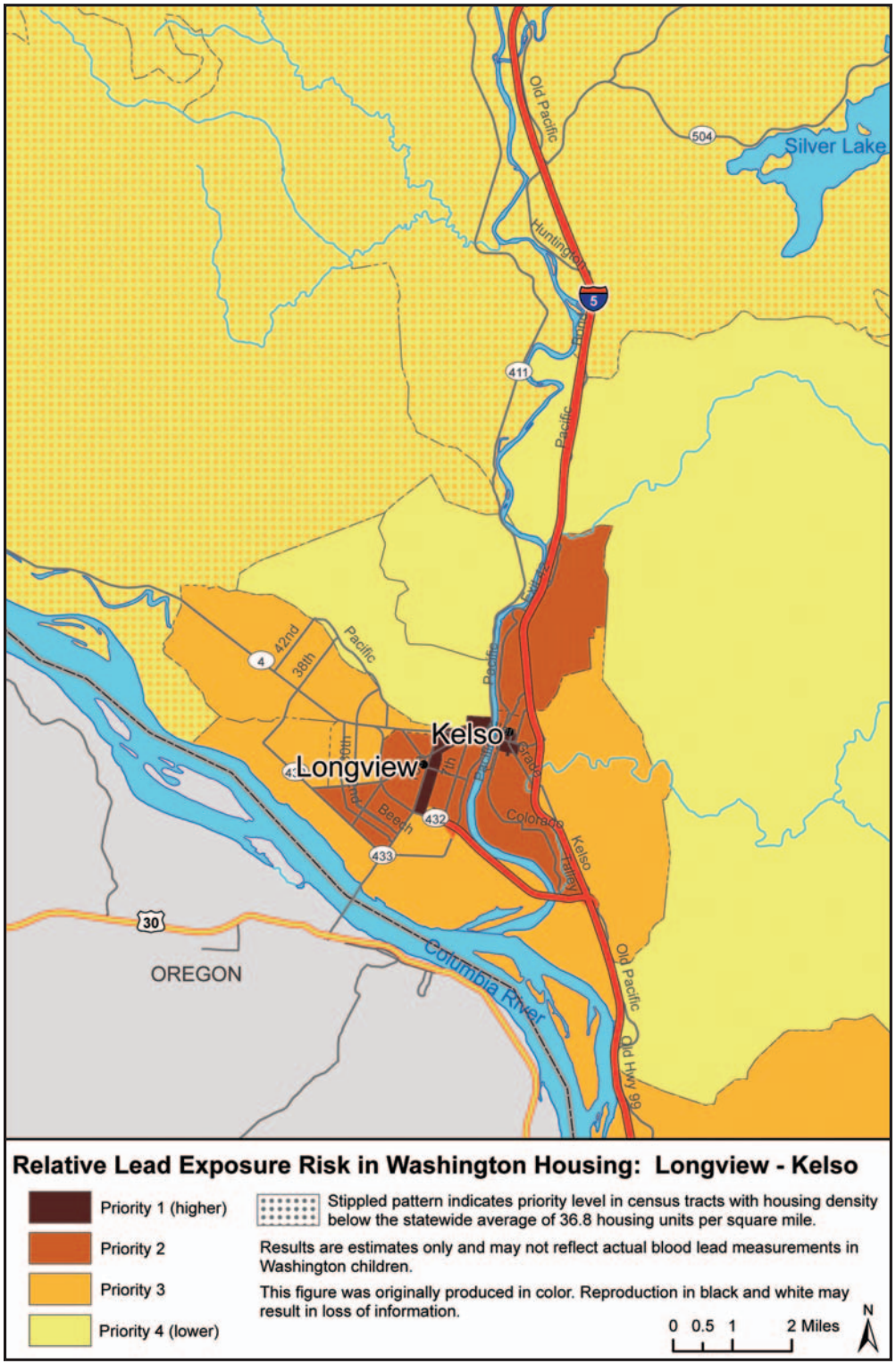
ABERDEEN - HOQUIAM

The Aberdeen and Hoquiam region contains old homes and a lower-income population, resulting in much of the area receiving Priority 1 and 2 ratings. Note that although the region to the north of Hoquiam received a Priority 2 rating, few homes exist in this area; the region received a Priority 2 rating because it is part of the same census tract as central Hoquiam and therefore received the same rating. Note also that the census tracts in and near Hoquiam were close to the risk level for areas receiving Priority 1 ratings, and there may not be a significant difference between the exposure risk in Aberdeen and Hoquiam.

CENTRALIA – CHEHALIS

Chehalis is estimated to contain a Priority 1 neighborhood, and the greater Chehalis-Centralia region is assigned a Priority 2 rating. Note that central Centralia does contain a high concentration of older homes and was close to receiving a Priority 1 rating; the difference between the exposure risk in central Centralia and central Chehalis may not be significant.



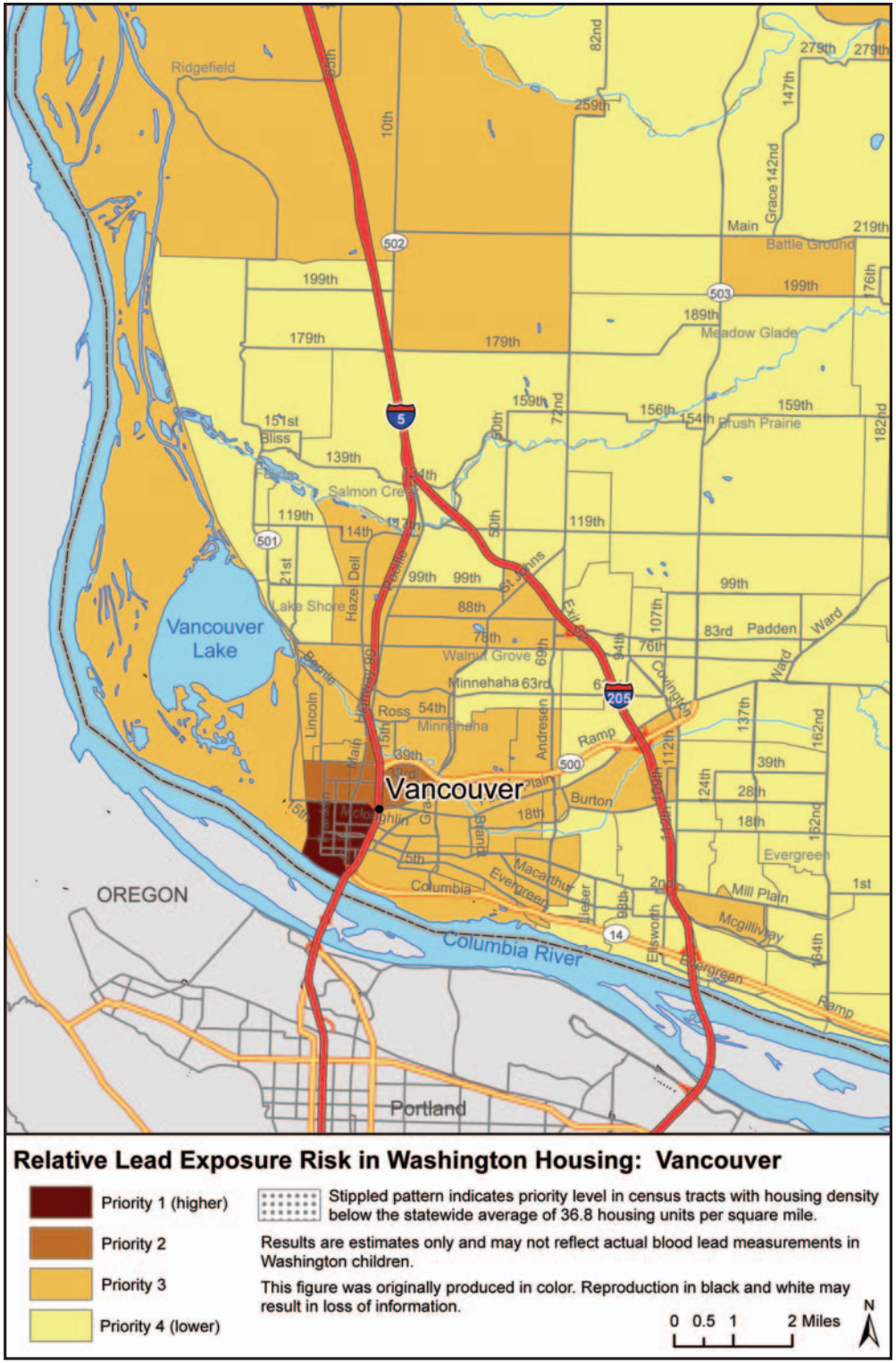


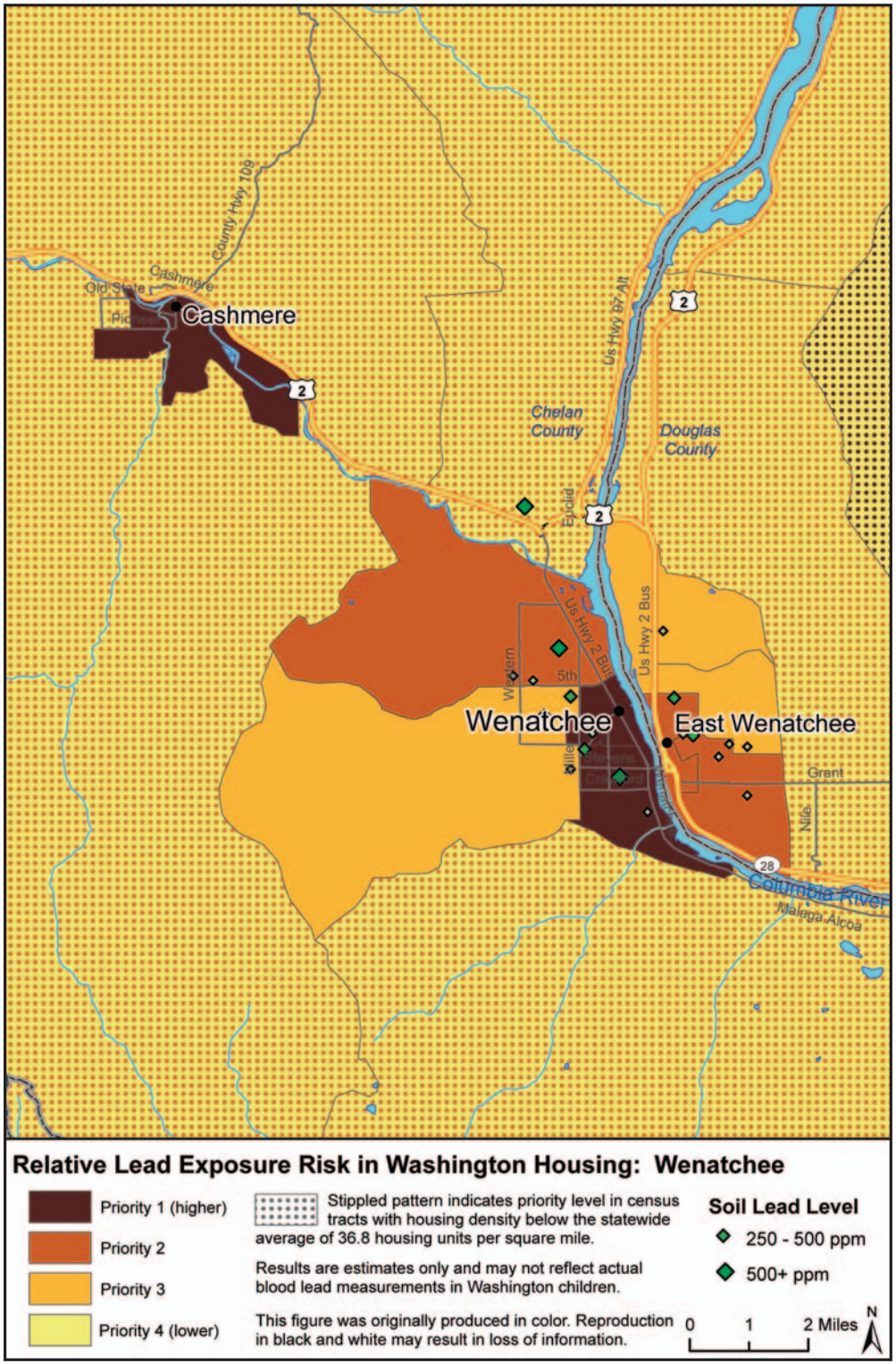
LONGVIEW - KELSO

Longview and Kelso both contain Priority 1 areas concentrated near and between the centers of these two towns, surrounded by Priority 2 areas that also have significant numbers of older homes. More recently developed neighborhoods, such as the area northwest of Longview along State Route 4, received lower priority ratings due to the relatively newer homes and more affluent residents.

VANCOUVER

Neighborhoods in central Vancouver received Priority 1 and 2 ratings due to older homes and a lower-income population. Northern and eastern neighborhoods received lower priority ratings.





WENATCHEE

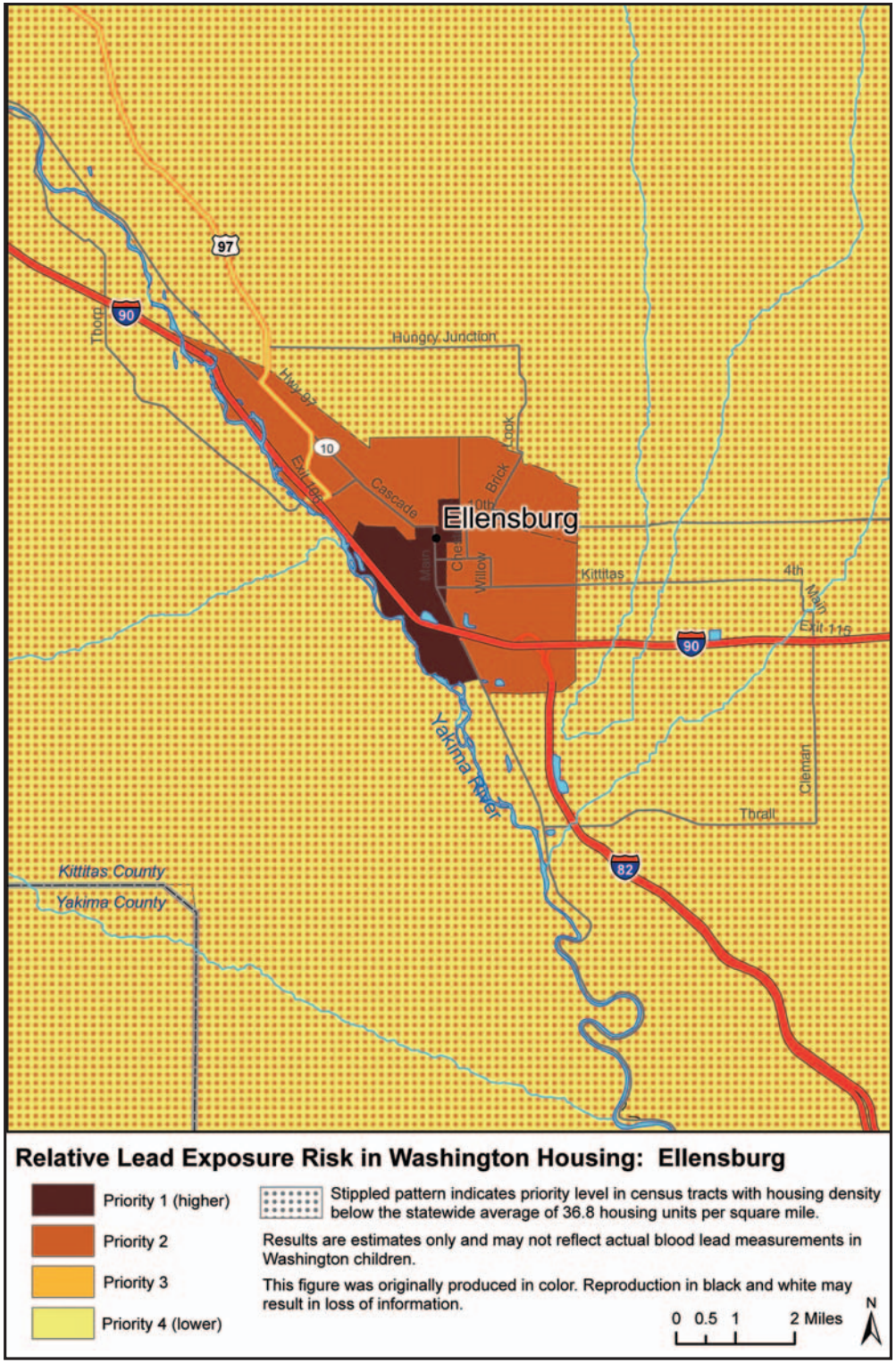
Central and southern Wenatchee have a high concentration of older homes and a generally lower-income population; these neighborhoods received Priority 1 ratings. Western Wenatchee and the community of East Wenatchee (across the Columbia River) received lower priority ratings. Note also that Cashmere received a Priority 1 rating, as does the very rural census tract in Douglas County that is partially displayed on the eastern side of the map. Much of the greater Wenatchee-Cashmere area received a Priority 2 area, and one additional risk factor that contributes to this higher rating is the relatively large fraction of residents who are Hispanic.

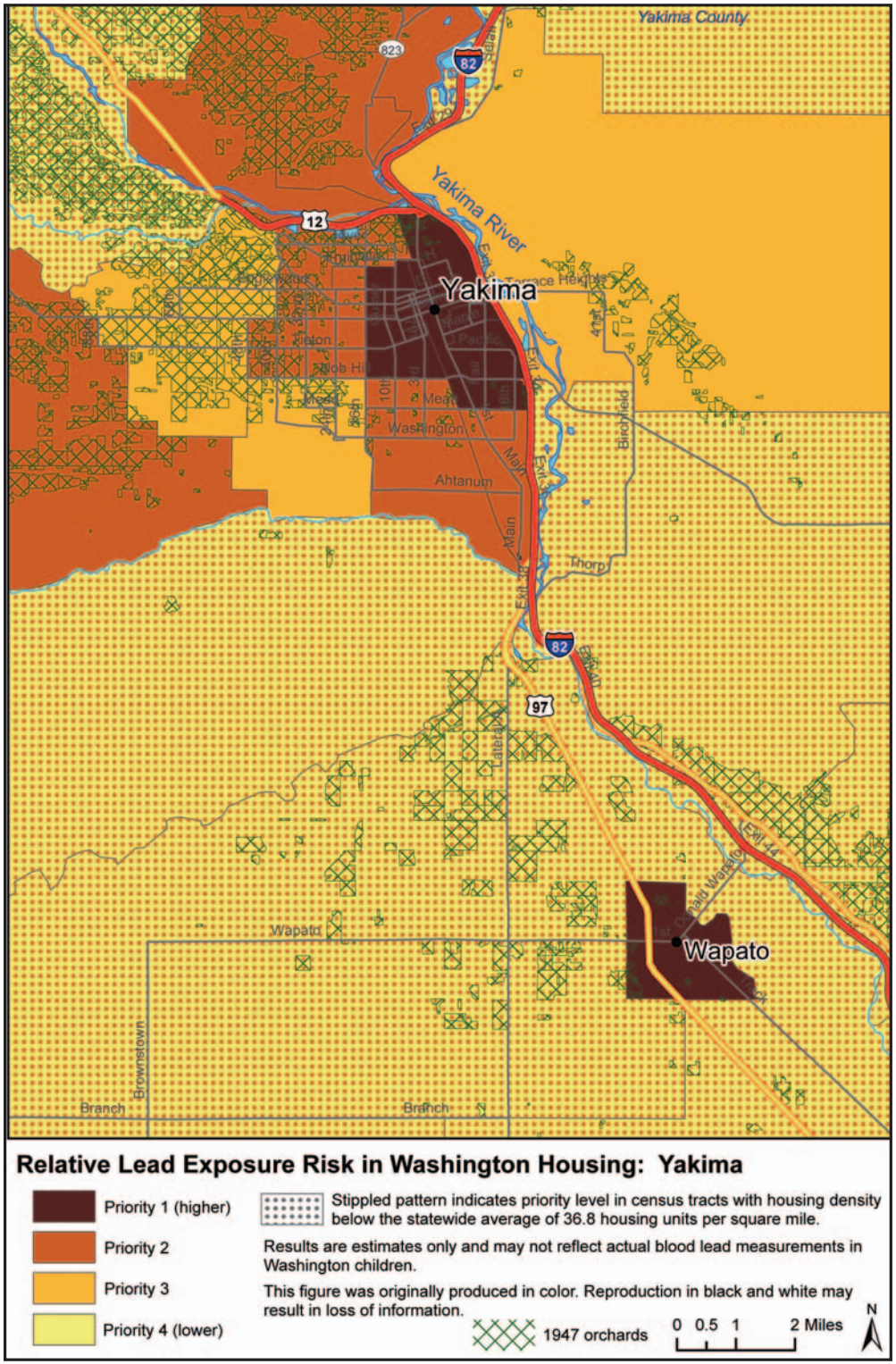
In addition to the housing and socioeconomic factors analyzed in this study, an additional factor in much of Central Washington, including the Wenatchee area, is potential soil contamination due to historic application of lead-arsenate pesticides in former apple and pear orchards.[15] Although the extent of possible former orchards in the Wenatchee area could not be mapped due to limitations in the available data, points on the Wenatchee map indicate soil samples, collected at schools, with elevated lead concentrations. These high lead levels (250 parts per million and above, the state standard) could be indicative of the influence of former orchards, which were more extensive in Central Washington (including the Wenatchee region) than in other parts of the state.

15 Lead-arsenate pesticides were used through 1947.

ELLENSBURG

Ellensburg contains Priority 1 and 2 neighborhoods due to its generally older homes, lower to moderate median household incomes, and location in Central Washington.





YAKIMA

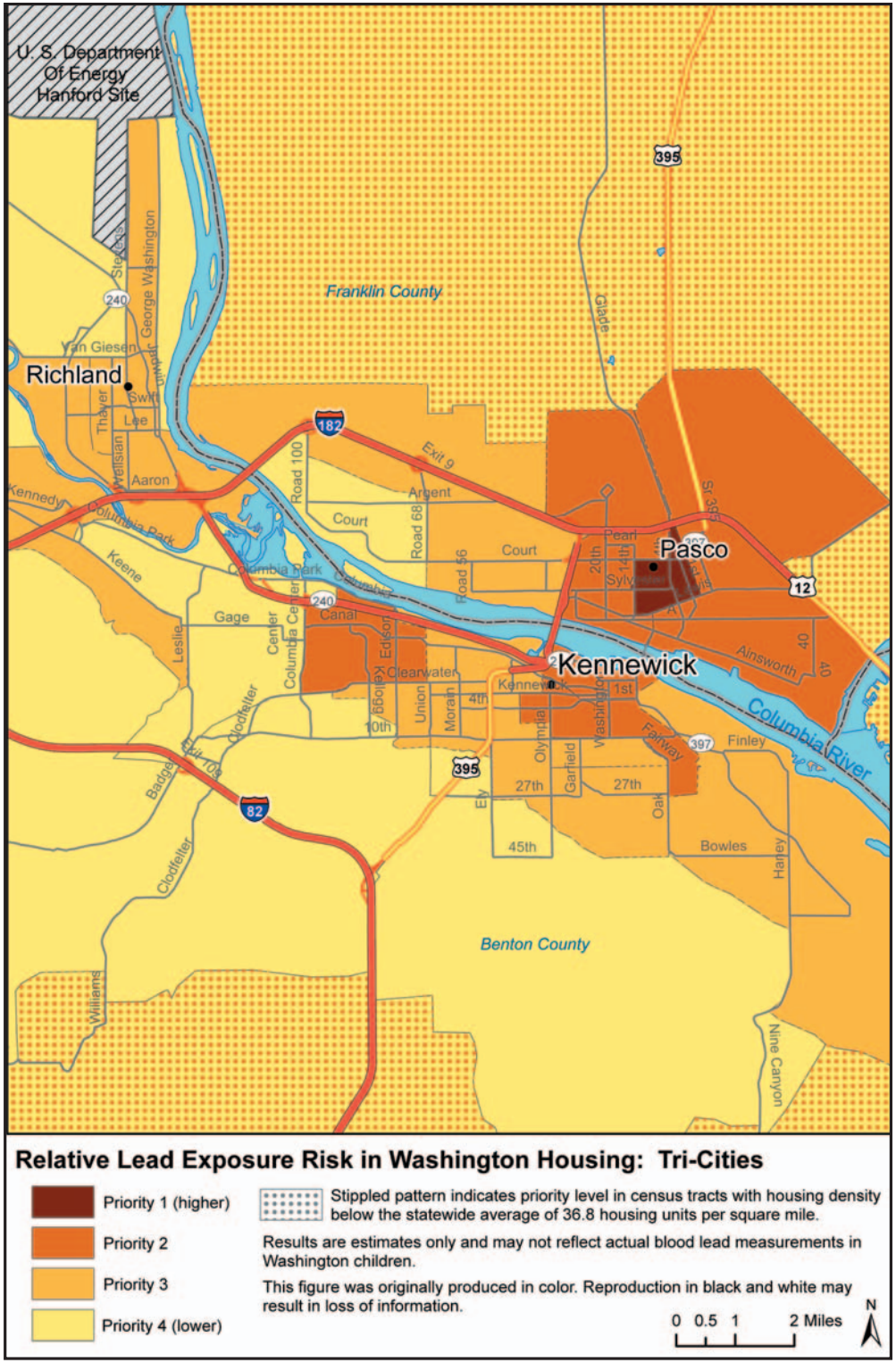
Central neighborhoods of Yakima and Wapato include high concentrations of low-income families, Hispanic residents, and many older homes, resulting in Priority 1 and 2 ratings. Newer and more affluent developments, generally to the west of Yakima, received lower priority ratings. Other portions of the Yakima Valley contain Priority 1 and 2 areas, ratings that were influenced by the location in Central Washington and the relatively high fraction of Hispanic residents, in addition to housing and socioeconomic variables.

In addition to the housing and socioeconomic factors analyzed in this study, another factor in the Yakima area, as in Wenatchee, is potential soil contamination due to historic application of lead-arsenate pesticides in former apple and pear orchards. One previous investigation, the Department of Ecology's Area-wide Soil Contamination Study, published maps completed by Yakima County of the possible extent of former orchard lands. Yakima County performed an analysis of historical aerial photographs to estimate the extent of orchards in the Yakima area circa 1947. These data are included on the Yakima map in this study to provide information on the potential extent of soil contamination due to lead-arsenate pesticides. Note that these data should not be substituted for a site-specific assessment, nor do they show the location of all orchards that operated during the period when lead-arsenate pesticides were used, between 1905 and 1947.

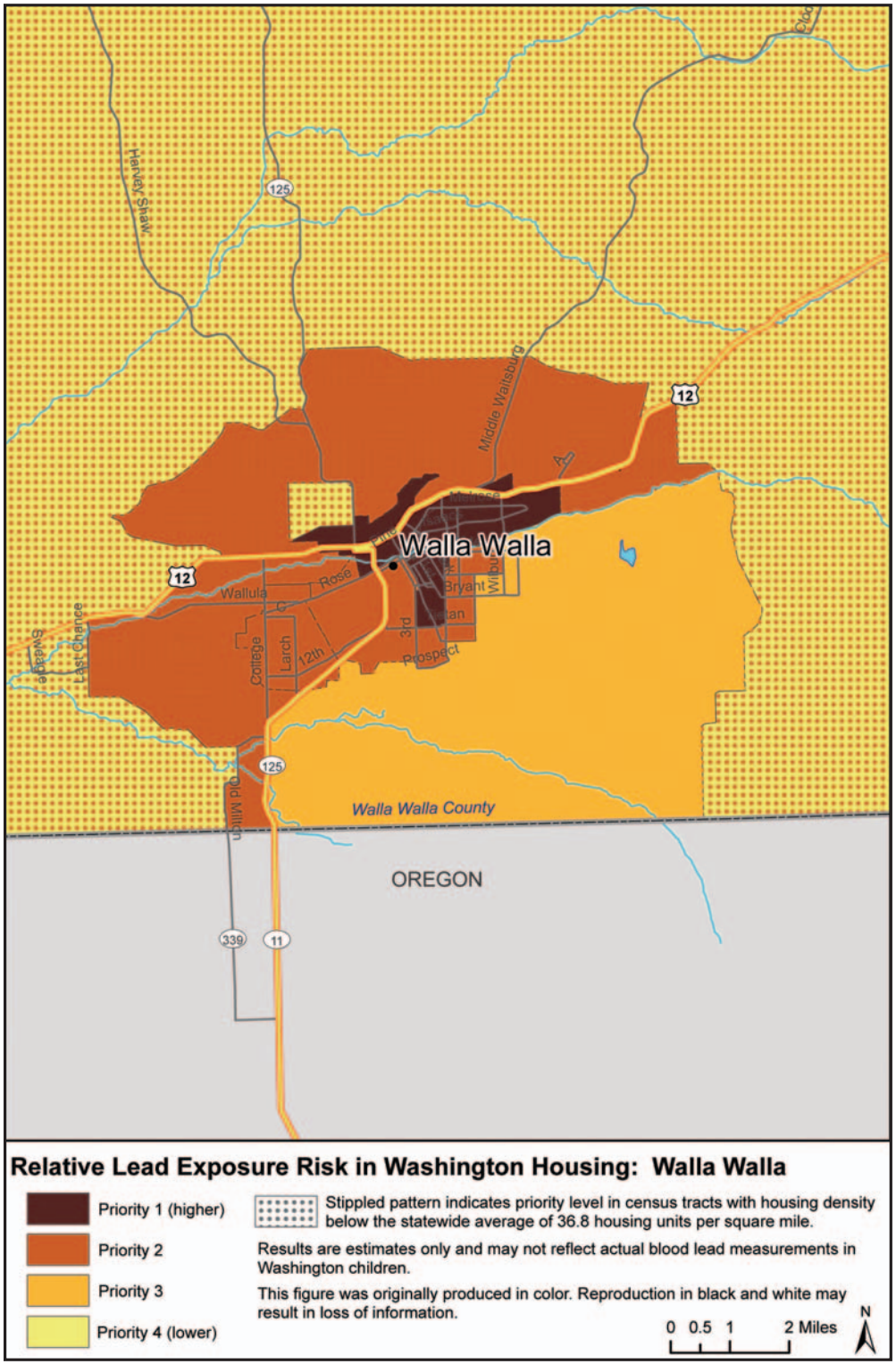
TRI-CITIES (RICHLAND, KENNEWICK, AND PASCO)

Much of the Tri-Cities area, including Richland, Kennewick, and Pasco, was generally developed in the latter half of the 20th century, and therefore homes in this region likely contain less lead paint than in other urban centers of the state. The center of Richland is one possible exception, as this area was built largely in the 1940s in conjunction with the Hanford nuclear facility. The center of Richland, however, is represented as a lower priority area on this map, a condition that may reflect a limitation of the assessment model used in this study. Although the statistical model relies on the percent of homes in a region built before 1940, lead paint is known to have been used in the 1940s, and so the relative exposure risk in Richland may be underestimated.[16]

Note that central Pasco received a Priority 1 rating; this rating is based on the high proportions of the population that are Hispanic and have lower incomes, as well as the moderate concentration of older homes.



16 The statistical analysis found that the percentage of homes in a region built before 1940 correlated more strongly with children's blood lead levels than did the percentage of homes built before 1950. The statistical model, therefore, uses the percent of homes built before 1940 (rather than 1950) as a predictive variable and would tend not to emphasize areas, such as central Richland, which experienced most of their development in the 1940s wartime era.

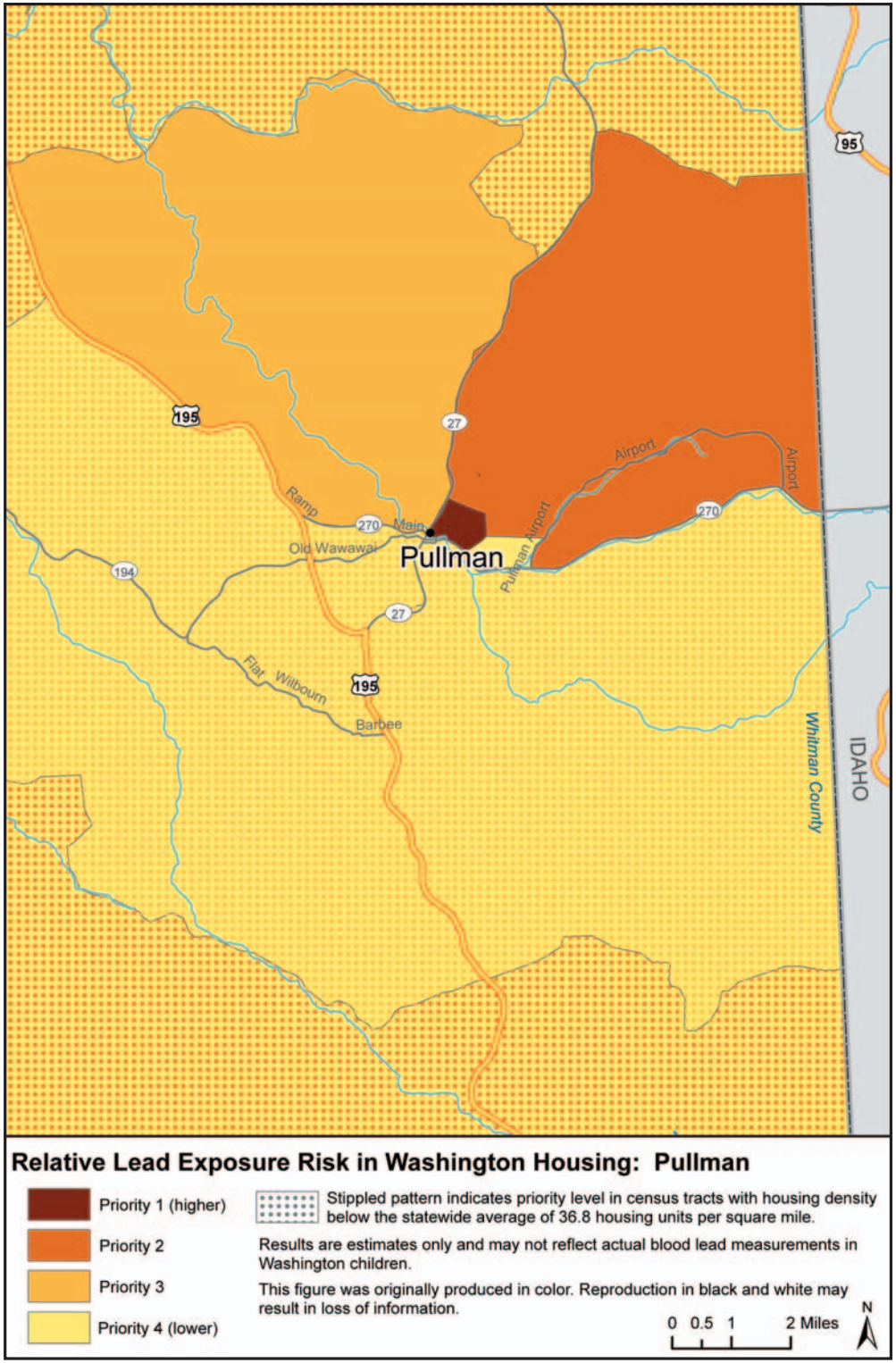


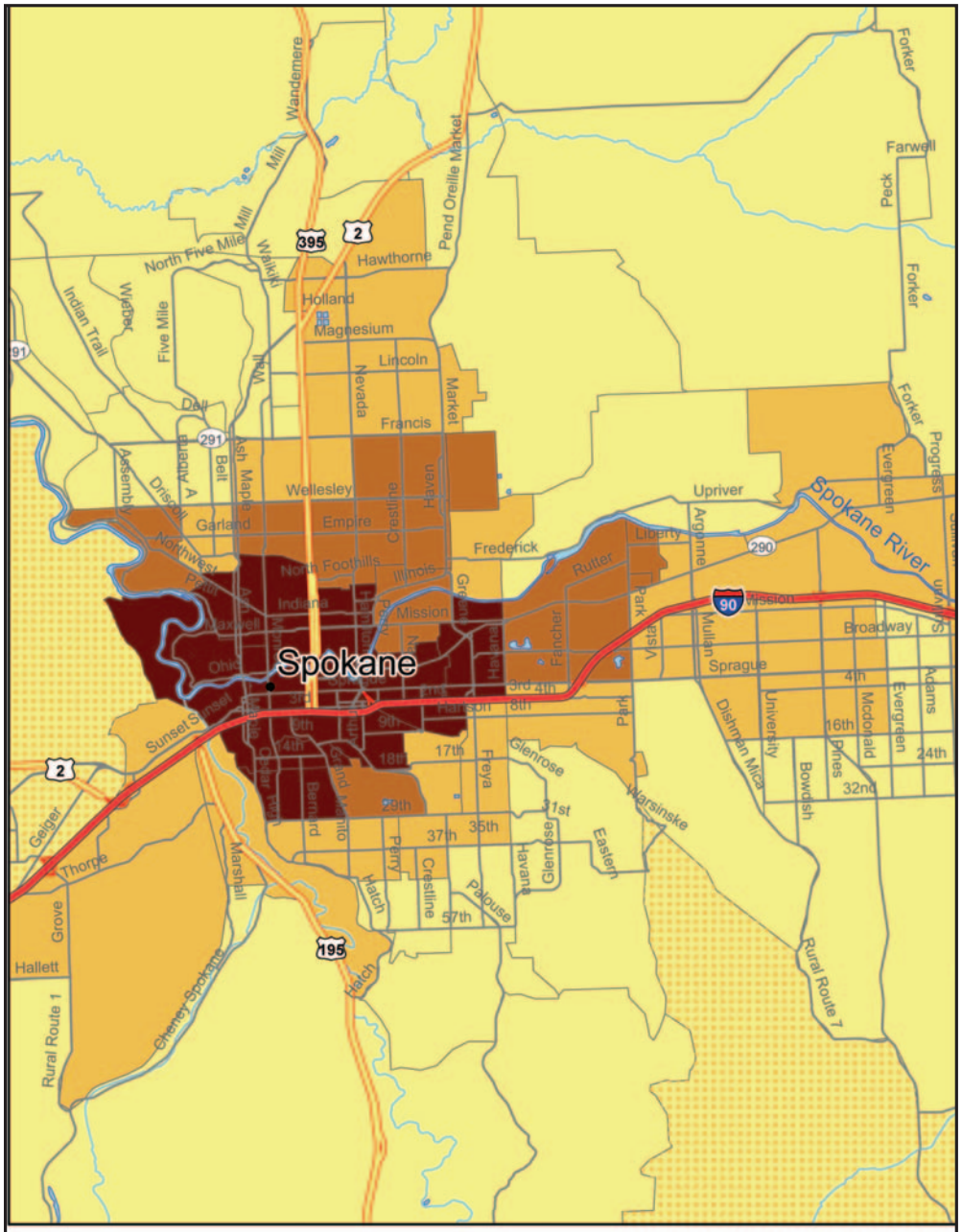
WALLA WALLA

Walla Walla has a relatively higher presence of risk factors for childhood lead poisoning in the center of town (Priority 1 and 2) and relatively lower concentration of risk factors to the south of town (Priority 3) where homes are newer, incomes are higher, and fewer residents are Hispanic.

PULLMAN

Like many other older communities in Washington, central Pullman received a higher rating (Priority 1). Neighborhoods in the northern part of the town were developed more recently and feature moderate median household incomes, leading to a lower rating of Priority 3. Neighborhoods to the northeast of town also have a lower fraction of older homes, but the low median income in this region leads to a Priority 2 rating.





SPOKANE

Central Spokane is estimated to have a high concentration of Priority 1 and 2 neighborhoods; newer and more affluent neighborhoods surrounding central Spokane have a lower presence of risk factors.

LOCAL MAP SUMMARY

As seen on nearly all of the 21 local maps, higher priority areas tend to cluster in or near the center of the older sections of towns. This finding is consistent with the development patterns of most communities, which have accommodated growth by building outward. Suburban developments constructed in the latter half of the 20th century likely either do not contain lead-based paint or contain paint with a lower lead content than homes built earlier. Many suburban communities also have higher median incomes than inner-city neighborhoods, perhaps decreasing the likelihood that lead-based paint is deteriorating or exposed in those homes.

CONCLUSIONS

This study relied on existing data sources to develop a model for identifying census tracts with relatively high risk of lead hazards to children in the home. Children living in the higher-priority census tracts are, on average, at greater risk for lead exposure. The information from this report might be used to identify geographic areas of the state where future health intervention efforts are likely to be most beneficial. Policymakers referring to this study should consider both the strengths and limitations of the existing lead data and the statistical model that was used.

The maps for the state are based on analysis of existing data and development of a predictive model. Because the study examined census tracts, a home's location within a Priority 1 area does not necessarily mean that a child in that home will have lead poisoning or even that residents of that particular home face elevated risks of lead exposure. However, residents of the area, on average, can be expected to face higher lead risks than those in lower priority areas. Additional research, including further blood lead testing of children or a systematic survey of lead hazards in and around homes, may be needed to validate the results and guide future public health investments.

The current study yielded these key findings regarding lead hazards to children in Washington homes:

- **Older homes, lower household incomes, Hispanic ethnicity, and Central Washington residence all help predict higher blood lead levels in Washington children.** Another possible risk factor is the location of residence relative to historic orchard lands.
- **Homes with higher relative risk for childhood lead exposure are generally located in neighborhoods developed by the mid-20th century.** Suburban areas built more recently tend to be lower priority areas.
- **Many of the older town centers with higher priority ratings are clustered in the Puget Sound region, though higher-risk areas are located throughout Washington State.** Priority 1 areas are found in Aberdeen, Bellingham, Ellensburg, Olympia, Seattle, Spokane, Tacoma, the Tri-Cities, Vancouver, Walla Walla, Wenatchee, Yakima, and other population centers around the state. Even small communities not represented on the maps may have significant exposure risk if they contain old homes (particularly if occupied by lower-income residents) or are located on land used for apple or pear orchards prior to 1947.
- **Of Washington's 475,000 children under the age of six, an estimated 36,000 (8 percent) live in areas designated the highest priority based on risk factors for childhood lead exposure in homes.** An estimated 93,000 children under age six live in the second-highest priority areas; 175,000 in the third priority areas; and 170,000 in the lowest priority areas.

Overall, children in Washington appear to face lower risk of lead poisoning than children in older, densely developed East Coast states with substantial lower-income populations. Nevertheless, this study indicates that significant numbers of Washington children may be at risk for lead exposure in their homes, a largely preventable situation.

More information about this study and additional copies of the report may be obtained through CTED's lead website: www.cted.wa.gov/lead.

APPENDIX – ADDITIONAL STATISTICAL NOTES

The Children's Environmental Health Initiative (CEHI), located within the Nicholas School of the Environment at Duke University, conducted the original statistical analysis to help develop the assessment model applied in this project. CEHI is a research, education, and outreach organization committed to fostering environments where all children can prosper. As part of its work portfolio, CEHI has developed a project that uses GIS technology to combine county tax assessor, blood lead screening, and U.S. Census data to create household-level priority models for childhood lead exposure. CEHI has developed this model for multiple North Carolina counties and is in the process of extending the model to other parts of the United States through its Lead Model National Replication Project. Duke's funding for this effort has been provided by the Centers for Disease Control and Prevention (CDC) and the National Institute of Environmental Health Sciences (NIEHS).

The Washington State Department of Community, Trade, and Economic Development contacted CEHI to help develop a predictive model to characterize the risk for lead exposure from lead-based paint in homes. Data available from Washington were not sufficient to support the tax parcel-based analysis that CEHI has used in developing childhood lead exposure risk models elsewhere. However, using GIS and statistical analyses, CEHI staff were able to construct a model for childhood lead exposure in Washington homes. This model was then revised by staff at the Washington State Department of Health to rely on a more representative subset of the blood lead data and to refine some of the statistical methods.

In particular, following are the results of the final linear regression model developed by the Washington State Department of Health based on CEHI's original model. The analysis was limited to the blood lead test results of children age 0-6 who were tested during the years 2000-2004 and whose blood was tested by labs that report geocodable address information for at least half of the children whose blood samples they test. There are 9,331 children who satisfy these criteria, and addresses could be geocoded for 7,128 of them. Thus the analysis was performed on these 7,128 children. The dependent variable used in the model was the natural logarithm of one plus the child's blood lead level. If a child had more than one blood lead test, the highest test result was used. The unit of analysis was the census tract, and each child's observation was weighted so that each census tract received a weight that was proportional to the number of children age 0-6 who live in the census tract. The analysis was performed in SUDAAN and used statistical methods that account for the clustering of observations within census tracts.

Table 1. Results of the Multivariate Statistical Analysis

Variable (Calculated at the census tract level)	**Coefficient**	**95% Confidence Interval**	**Standard Error**	**p-value** (Significance)
Intercept	0.9135	(0.7010, 1.1259)	0.1082	0.0000
Fraction of housing built pre-1940	0.6094	(0.3150, 0.9038)	0.1499	0.0001
Per $10,000 median household income	-0.0557	(-0.1111, -0.0004)	0.0282	0.0484
Fraction Hispanic ethnicity	0.1885	(-0.0046, 0.3815)	0.0983	0.0557
Central Washington residence	0.1029	(0.0125, 0.1932)	0.0460	0.0257
Per $10,000 median house value	0.0093	(0.0001, 0.0185)	0.0047	0.0478

n = 7,128

Counties identified as Central Washington include Adams, Benton, Chelan, Douglas, Franklin, Grant, Kittitas, Klickitat, Okanogan, Walla Walla, and Yakima.

Note that the housing age variable that the Duke and DOH researchers ultimately selected was the percentage of homes built before 1940. Other studies have more often used percentage of homes built before 1950. The analysts did find a strong relationship with pre-1950 homes, but they found that the pre-1940 variable was an even stronger predictor of blood lead level given the child blood lead data available.

APPENDIX – ADDITIONAL STATISTICAL NOTES

The following table presents summary statistics on the explanatory variables used in the final regression analysis.

Table 2. Summary Statistics on Data Used in the Statistical Analysis

Variable	Data source	Mean	Standard Deviation	Median	Range
Fraction of housing built pre-1940	2000 U.S. Census	0.13	0.16	0.07	0-100
Per $10,000 median household income	2000 U.S. Census	4.76	1.69	4.54	0-13.38
Fraction Hispanic ethnicity	2000 U.S. Census	0.07	0.10	0.04	0-0.82
Central Washington residence	See above	--	--	--	0-1
Per $10,000 median house value	2000 U.S. Census	16.95	8.55	15.13	0-79.81

Based on the statistical analysis results presented in Table 1, the following equation was applied to each census tract in Washington:

ln(Maximum BLL+1) = 0.9135

\+ 0.6094 * Fraction of housing built pre-1940

\- 0.0557 * Per $10,000 median household income

\+ 0.1885 * Fraction Hispanic ethnicity

\+ 0.1029 [If residence in Central Washington]

\+ 0.0093 * Per $10,000 median house value.

Output ranged from 0.65113 to 1.97967 and was classified as follows into four priority levels using the Jenks natural breaks statistical method.

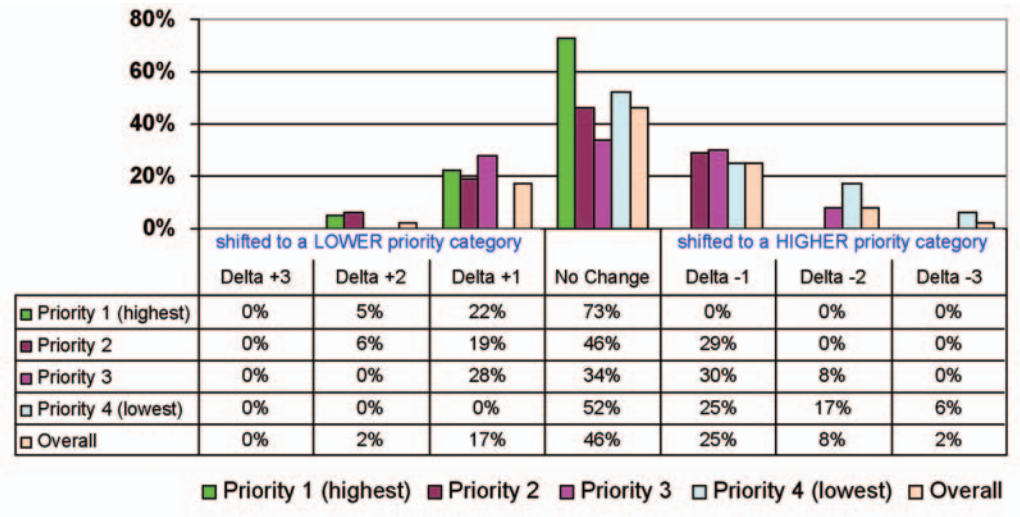
Table 3. Break Points for Each Priority Level

Priority Level	Range of ln(Maximum BLL+1)
1 (Higher)	1.12643 - 1.97967
2	0.95366 - 1.12642
3	0.82787 - 0.95365
4 (Lower)	0.65113 - 0.82786

APPENDIX – ADDITIONAL STATISTICAL NOTES CONT.

As a measure to test the reliability of the above model at assigning census tracts to one of the four priority levels, faculty and staff at the University of Washington conducted Monte Carlo statistical simulations using software called Crystal Ball. The simulations were designed to test the reliability of the model – given the uncertainties in model coefficients – in assigning census tracts into one of the four priority levels. Figure 1 summarizes these results. Results of the analysis indicate that the model performs the best at assigning the highest priority category. In particular, in 10,000 trials, the model assigned the Priority 1 census tracts to the top priority 73 percent of the time. Because Priority 1 census tracts are likely to attract the most attention from the report's audience, this measure was considered highly encouraging – meaning that we have the most confidence in the model for the risk category that is also of greatest interest and concern (Priority 1).

Figure 1. Proportion of Under- and Over-estimation of Blood Lead Level Risk Categories Due to Model Uncertainty (in 10,000 Trials)



	Delta +3	Delta +2	Delta +1	No Change	Delta -1	Delta -2	Delta -3
Priority 1 (highest)	0%	5%	22%	73%	0%	0%	0%
Priority 2	0%	6%	19%	46%	29%	0%	0%
Priority 3	0%	0%	28%	34%	30%	8%	0%
Priority 4 (lowest)	0%	0%	0%	52%	25%	17%	6%
Overall	0%	2%	17%	46%	25%	8%	2%